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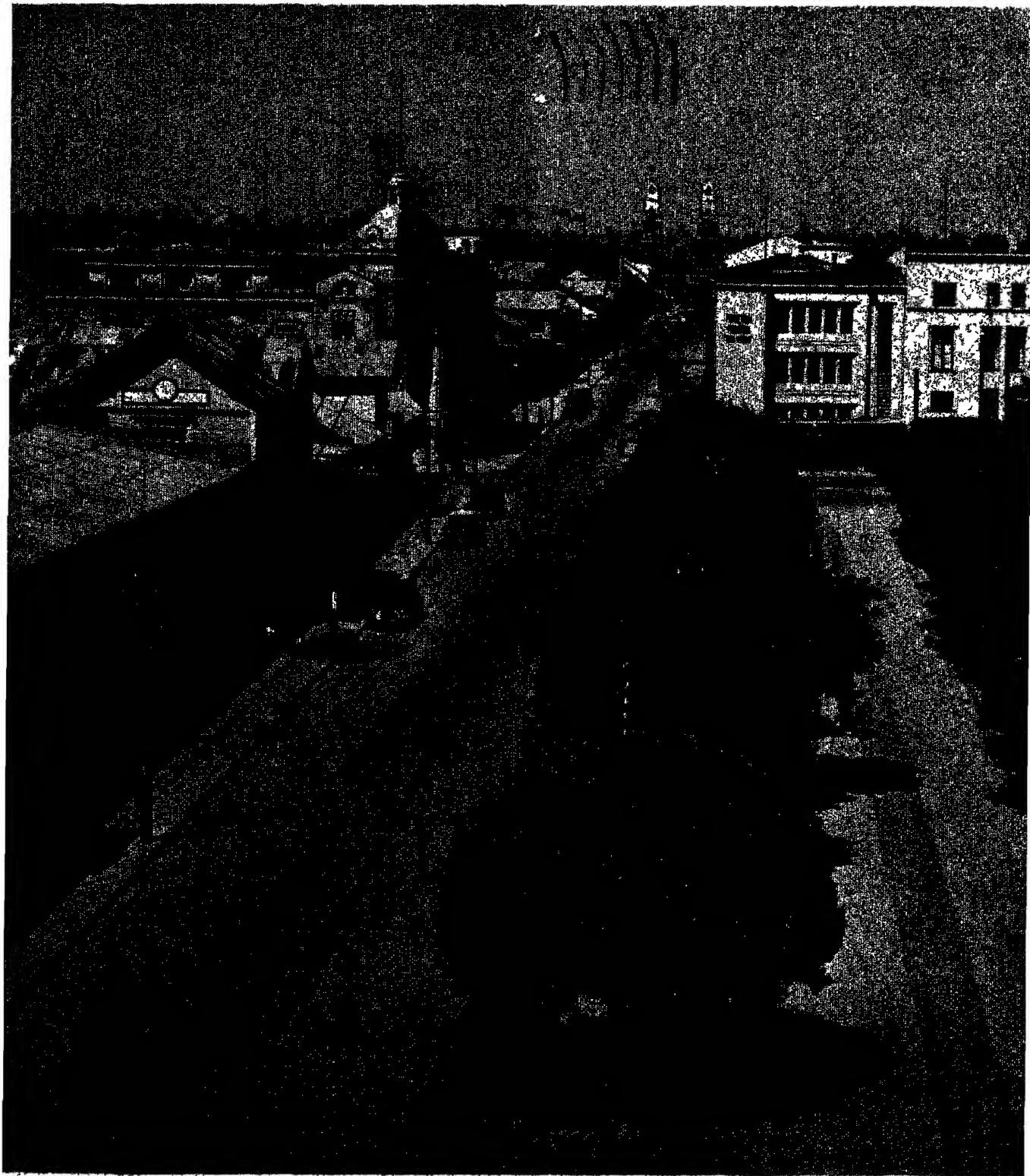


INDIAN CONCRETE JOURNAL

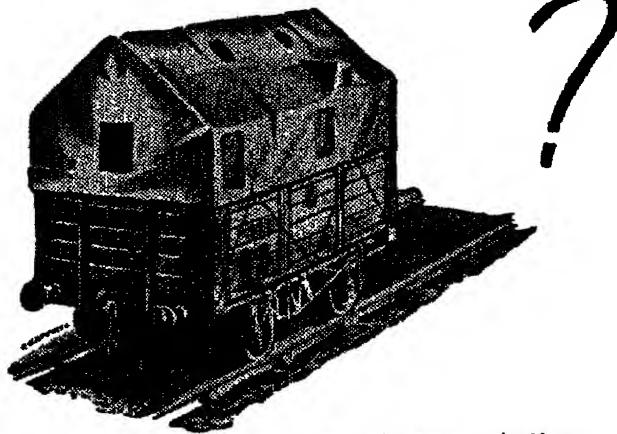
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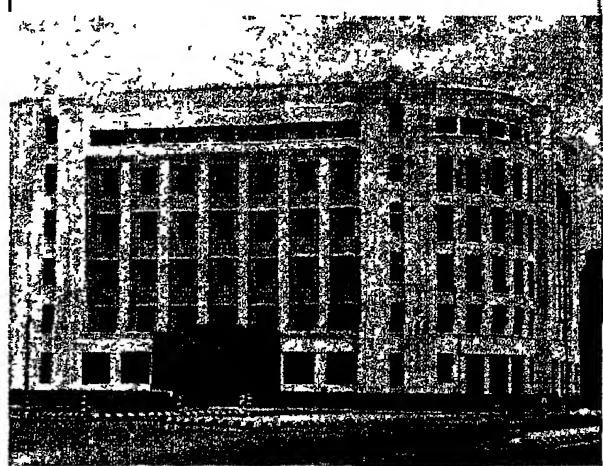


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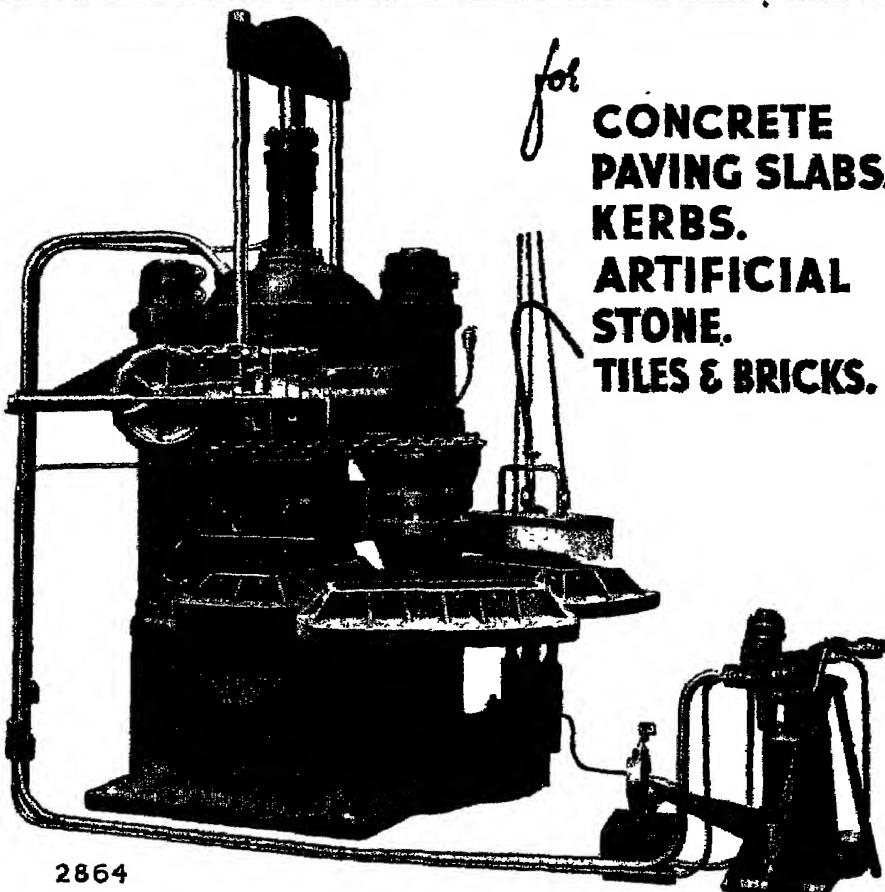
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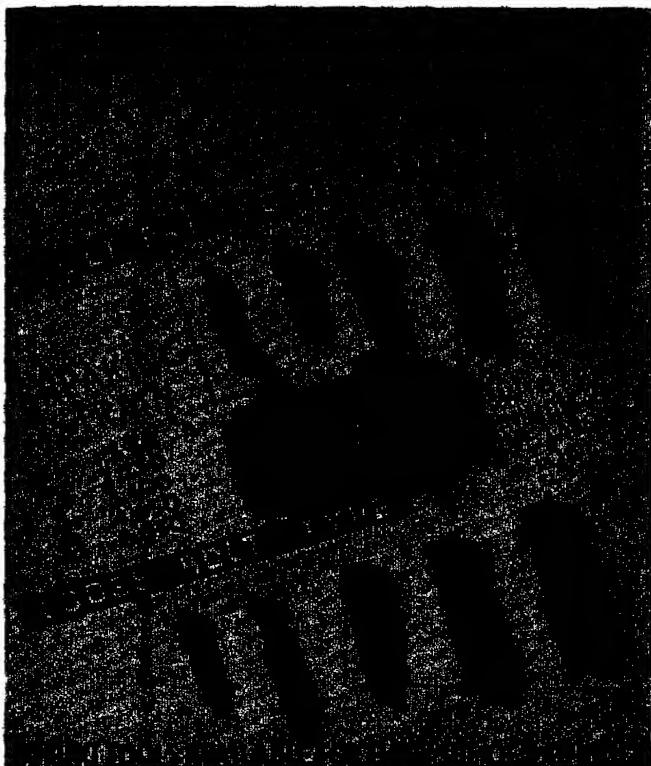
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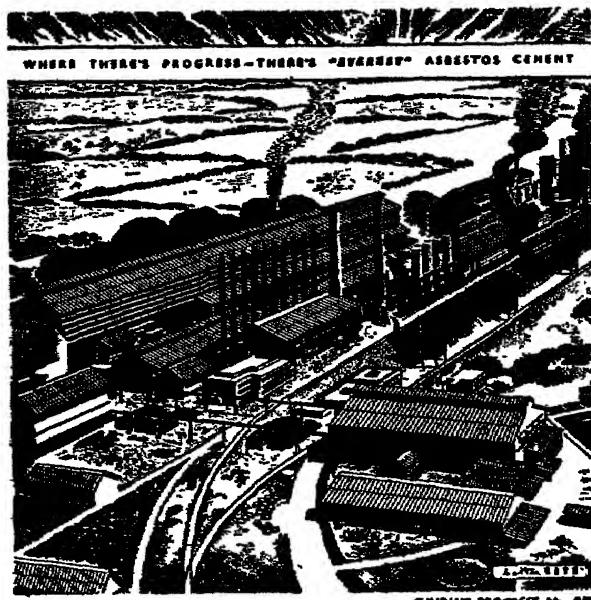
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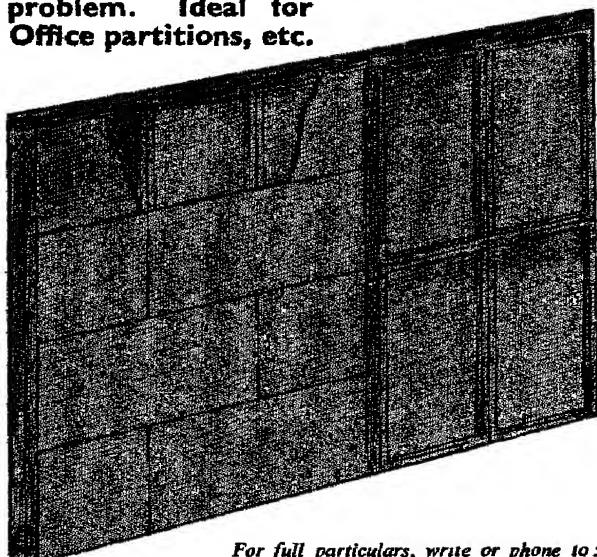
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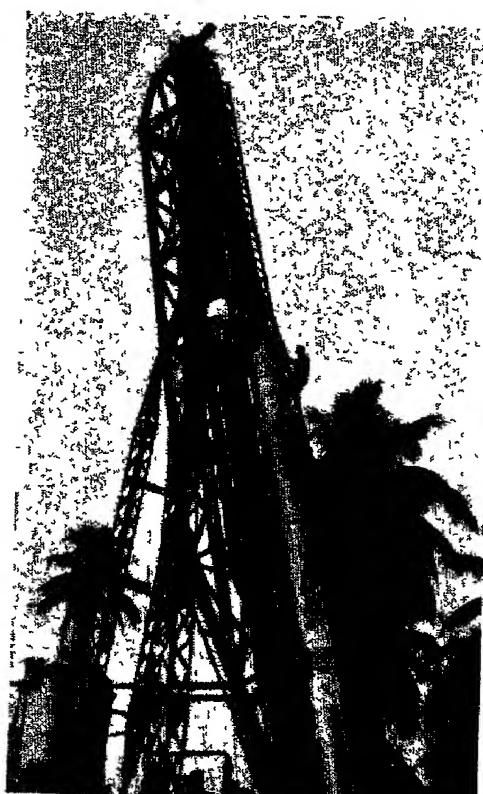
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EDITORIAL NEWS & NOTES



Village Development

Summary of talk given by Mr. T. R. S. Kynnersley, at the Bombay Centre of the Institution of Engineers (India) at Haco House, on Wednesday, the 18th of April 1945.

General.

There are some seven hundred thousand villages in India, and the vast majority of villagers are existing at a very low subsistence level.

In this connection it is pointed out that India grows only 800 lbs of rice per acre, against 1,450 lbs. in the U.S.A and 3,000 lbs. in Italy.

In the case of milk, in spite of the fact that India has two hundred million cattle, one for every two human beings, the yield per cow is extremely small, being just over two lbs a day, compared with the corresponding yield of 20.5 lbs in Holland, and 15 lbs in England. The fat content of the milk of the Indian cow is greater than that of the milk of the western cow, but this does not nearly make up for the lack of yield.

We must recognise the fact therefore, that progress is mainly going on, in the towns and cities. It is also a fact that more and more young men, and even women are being attracted to the towns and this is specially true in the present war-time period with the inevitable result that the towns are being crowded out, and the intelligent section of the country side is being reduced. This is obviously an unhealthy state of affairs in view of the fact that the towns have to be fed by means of the agricultural pursuits of the country.

By comparison with Russia, America, and the United Kingdom the output per acre of all agricultural products is extremely low, and until the general standard is raised, it is doubtful if the food position which is after all a question for every one, can be materially improved.

You may ask me in what way is this a subject for discussion by a body of engineers. My reply is that engineers are the very people who ought to be the first to give assistance.

In this connection I would refer to Sir Manilal Nanavati's excellent book on the Indian Rural Problem, and in Chapter 10, he considers at some length the role of the engineer, and if his recommendations are acted upon, we should at once get a very great improvement in the general outlook of the countryside.

Main Immediate Requirements of the Villager.

- Water Supply
- Housing
- Sanitation
- General Cleanliness
- And Access.

Water Supply.

Taking them in turn, water is an obvious necessity both for the people and for all crops. Here the engineer is required to develop all means of getting

water where it is wanted. Irrigation schemes, using dams from the biggest to the smallest, bunding to retain water where it is required, wells both shallow and deep, bore-holes and the necessary machinery to raise the water to the surface, which includes windmills and many primitive devices right up to the modern electric or petrol driven pump. This introduces the need for universal current which must be supplied through grid systems, from power generated by hydro-electric plants, or by thermal stations using coal or oil. There is also scope for the engineer in thinking out methods by which the cultivator can get water to the area in which it is required, by irrigation channels, etc.

Housing.

For the better health of the villager better housing is required for himself, his wife, and his family, and also for his cattle. The houses should be well ventilated, proof against monsoon storms and rain, and as far as possible vermin, and fly proof. Any one who knows the Indian village, must realise the fly nuisance. These insects sit on every conceivable piece of dirt, and then on the food, and milk and contaminate these. This is bound to bring disease.

Sanitation and General Cleanliness.

After the war it is hoped that the engineer and the chemist, will assist in exterminating or at any rate in excluding the fly and incidentally the mosquito from human habitation, and one of the first things obviously to be done is to segregate animals from human beings. But to make this possible and to give a feeling of security to the people proper fencing arrangements must be made to keep off dacoits and thieves by some system of strong points to be used for protective guards. Once the people feel safe from thieves and robbers, there should be no objection to communal stabling.

- All stables must be provided with.—
- (a) easily cleaned flooring,
- (b) drains for ready washing out,
- (c) Suitable managers and drinking troughs,

(d) Manure pits with covers

Poultry houses and pig-sties, should also be provided with readily cleaned quarters. Special lock up sheds should be provided for agricultural machinery and implements. Permanent threshing floor made impervious to rain water and khattis for grain storage must be designed for the protection of the produce from flies and other vermin.

Access.

Good hard roads or trackways should

be made from the centre of the village radiating outwards as required and these roads should be provided with proper drainage, so that they can be readily maintained and kept clean. Connecting village to village and village to railway station, or main road, there must also be permanent and readily maintained trackways or roads.

Amenities.

All work and no play cannot make for a balanced way of living, and therefore, suitable halls and meeting places must be provided where travelling cinema shows can operate, where radio can be heard in comfort, and where social uplift meetings can be convened.

Cottage Industries.

Once the comforts and general amenities are provided the villager in his spare time (of which at present he has a great deal) can turn his attention to cottage industries for increasing his income. There are no limits to the work that can be done, if only the villager can be given sufficient energy to use his spare time in this manner. Energy comes from good health, and one of the main sources of good health is proper nutrition. Proper nutrition should be a subject of intensive study, and here health and general betterment societies should play their part.

Individual members of the Institution can very well help on lines explained by Mr. Collins in the Bombay Provincial Rural Development Board, at the Council Hall, last Monday. Amongst many other constructive suggestions he said that the success of hydro-electric projects would depend on the demand for lighting, for dams, for irrigation and small industries, particularly those which he hoped would be started by mechanically minded returning soldiers.

If mechanically minded returning soldiers are expected to use their brains towards this work, how much more should civil engineers belonging to this and kindred Institution help?

Agricultural implements.

Here we have a vast field for the engineer and scientist, as well as for our legislators. Collective farming has been a great success in many countries of the world, and there is no reason why it should not be a success in India. It will mean a radical change of ideas on the part of the people, but if success is to be obtained, such change of ideas is absolutely necessary. Once collective farming is introduced, it will be possible for machinery to take the place of many of the old-fashioned implements in use to-day. Agricultural experts exist, who know what ought to be done. Machinery suppliers will be ready shortly to supply the necessary tools, but the desire for improvement must come from the villager himself; therefore, the first step appears to be to educate him and his family to demand a higher standard of living.

Here we are reminded of the great Tennessee Valley project in America, which was very clearly shown recently in Bombay, by an excellent cinema picture. From this we learn that when the project was mooted, the villagers mainly objected to interference with their private lives, their old-time methods. These objections were finally broken down by one or two far-seeing farmers, who participated in the new work, thereby enriching themselves to a very great extent. The objectors seeing the value of the project through actual results, changed their minds, and became fully enthusiastic themselves. Such projects can very well be introduced in this country, but they will need not only Government aid, and Legislation, but a considerable amount of educative effort to break down the conservatism of the existing farmers. Here again individual members of the Institution can help, for every time they go on leave to the villages, they can use their knowledge and experience to explain to the villagers the value of improved methods of agriculture and co-ordinated effort. In this way the true seeds of advance will be sown.

What is Being Done.

Provincial Governments and Indian States are gradually recognising the necessity of revolutionising their methods in dealing with the villager and education of the peasant. It is understood that steps are being taken to bring home to the villager the necessity of helping himself to a better life, by means of educative publicity, both through the radio and through travelling vans. If these vans could show contrast models, they would be of immense value, and this should give scope for engineering ingenuity, for just as the famous Bailey bridge, which has been so useful in war was invented as a result of a meccano toy, so fruitful ideas can be obtained from building blocks and prefabricated model units.

What others say.

Lenin is reported to have said :
" Small farming cannot extricate itself from poverty."

More capital must be introduced into farming, and a readier system of equitable exchange built up between the cities and the country, so that each may reap the benefit.

Quoting from Bimal C. Ghose's excellent booklet entitled "Planning for India" :

" Without improved implements and machinery in the processes of cultivation, neither productivity of agricultural labour nor agricultural output can be materially increased, and without such expansion in agriculture paralleled by a simultaneous industrial development there is no prospect of an appreciable improvement in the wellbeing of the masses."

Large Scale Industries.

Lastly I will refer briefly to the known desirability of introducing large scale industries into the country. There is no doubt that industrialists should be encouraged and guided by the Central Government, to open up heavy industries, but where possible these should be situated away from existing towns, though they must be near railways and preferably on the national highway grid for easy access; but wherever they are placed may I plead for proper town planning of these new centres right from the start and in this planning our engineers can surely help.

APATHY TOWARDS TRANSPORT AND LACK OF VISION

We reproduce below the editorial comments made by "Highways, Bridges and Aerodromes" in their issue of the 21st March 1945.

ON every hand transport is acknowledged to be the most vital of public services. The most backward countries are those without it. They live in abysmal ignorance, from which they fail to emerge until the more enlightened nations find it in their interests to educate them. India, as a unit of the British Empire, is an outstanding example of the ill-effects of neglecting communications—a state of affairs to which, at long last, the Indian Government is giving its attention. In any civilised nation there are many things which have come to be vital necessities in the life of the community, but for the maintenance of each and every one of them transport is a necessity. Transport sustains and irrigates everywhere it touches. The only places where it is not required is where there is nothing to transport. These are purely axioms which too frequently are disregarded. It is curious—in fact, it is tragic—that in a country such as this there should be so much apathy towards transport. It is a small, compact, highly industrialised country, in which transport could be made to be more facile, more convenient, and more economical than in any part of the world, this being because there is such an enormous demand for transport over comparatively short distances, a demand which has never been met satisfactorily since England became the industrial centre of the world. It is surely a reproach on our inland transport organisation that it still costs as much to move a

ton of goods a matter of a hundred miles or so as to move it from the Antipodes to this country. Transport is a charge on the community from which none of us can escape, and we have to purchase it, however ill we can afford it, and that is why the profit seekers and those who can control it are merciless in their exactions. Amongst these the Government is undoubtedly the principal transgressor by its unreasonable taxation and misapplication of the accrued yield. Profit is placed before service, which is a fact the man in the street is only just beginning to realise. Air transport—the newest comer in the field—has of late assumed proportions little dreamt of only a few years ago, and it is interesting to follow the reaction of the Government to it. Its attitude appears to be similar to that which it holds towards road transport—namely, that rail transport must have first consideration—but it cannot obstruct air transport in the same way it has that of road transport for the reason that air transport needs no constructed tracks. As for road transport, the simple way to prevent it becoming a serious rival to rail transport was to deny it the suitable tracks required for its development, and, further, on the excuse that the roads were not suitable for fast and heavy traffic, to impose the heaviest taxation, the most severe regulations and irksome control it has been possible to devise. Still further it has encouraged the railways to absorb road transport, to get control of it, and to use it as a kind of handmaiden for railways service, even though it can be proved that it can compete in every field of railway service and outclass it in many fields. By doing this it has prolonged the solvency of the railways, but has increased the cost of transport

in so doing, and has imposed a heavy burden on industry and on individuals of the community, and the country remains quite inadequately serviced.

It proposes to take a shorter cut with air transport by handing over the internal routes *holus bolus* to the railways, whilst reserving to itself nominal control. Similarly, it proposes to hand over the ocean routes to ocean shipping lines. Thus the Government seeks to create three great transport monopolies, the one in which we are most interested being the railway monopoly of road transport and internal air lines. There does not appear as yet to be any intimation as to who are to provide, organise, and own airports, aerodromes, landing strips, and so on, but proposals will no doubt shortly be forthcoming.

In all this transport confusion and biased legislation road transport is ploughing a lonely furrow. It is denied even that which is essential to it. It is not even permitted to build or acquire types of vehicles which are much needed to provide better service at home, and which the manufacturers know are necessary for export purposes if they are to compete on equal terms with other nations in the world markets. All this on the excuse that the roads are unsuitable for larger and heavier vehicles!

More than half the road transport trouble arises from the fact that there is no unity of effort to obtain requirements common to all. As for road haulage, better roads would provide cheaper running costs, and so cheaper transport, which would in turn infuse more life into industry and create a greater demand for transport.

SHELL CONCRETE CONSTRUCTION

[By Dr. K. HAJNAL-KONYI, M.I.Struct.E.]

Part I. Barrel Vaults.

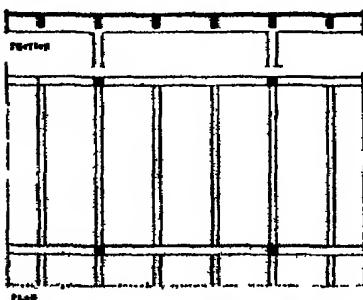
The Zeiss-Dywidag system of shell concrete construction is a landmark in structural evolution in that it allows spans of unprecedented width without intermediate supports to be covered at low cost. This article describes the system both in theory and practice. The first part deals with barrel vaults and the second with domes. The author had much practical experience of the system in Germany before the war and was closely connected with the construction of the Frankfurt Market Hall, one of the buildings illustrated here.

1. Introduction.

The characteristics of shell construction* can best be appreciated by comparing them with those of the usual forms of construction in traditional materials and with the gradual development of new forms in reinforced concrete. The traditional building materials, such as timber, stone, brick-work and steel, have the common feature that they transmit loads substantially in one direction only, e.g. the typical form of a roof construction, both in timber and steel, is a combination of (1) main girders or trusses spanning across the building; (2) purlins, spanning between the trusses; (3) rafters, spanning between the purlins; (4) covering material or sheathing between the rafters.

The introduction of reinforced concrete made possible a fundamental change of principle. A concrete slab, if reinforced in a suitable way can transmit loads in any direction in its plane. It took some time before this essential feature

* Data about the Zeiss-Dywidag system of shell construction were published in Information Sheets Nos 515, 517, 520.



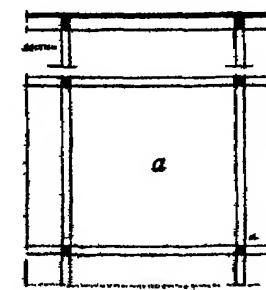
1. Reinforced concrete slab spanning in one direction between beams.



4. A vault based on the same system as Fig. 1.

of reinforced concrete was realized in practice. In the early years of its application only slabs spanning in one direction were used. An example is shown in Fig. 1. A continuous slab (a) is spanned between secondary beams (b) which in turn are supported on main beams (c). These transmit the load to the columns (d). Fig. 2 shows a simplification in the layout of the beams. The slab (a) is spanned in two directions. There are no secondary and main beams, all beams (b) support the slabs directly and are supported directly on the columns. A further development is illustrated in Fig. 3. Here the beams are omitted entirely and the slab is supported directly on the columns, which have properly shaped heads or caps. Whereas the arrangement in Fig. 1 may be carried out in any traditional building material, that in Figs. 2 and 3 is characteristic of reinforced concrete. The advantages from the architect's point of view of the possibilities of Fig. 2 as against Fig. 1, and those of Fig. 3 against both Figs. 1 and 2 are obvious.

The Zeiss-Dywidag shell system is a somewhat similar development of the vault. Fig. 4 shows a cylindrical roof where the slab is supported on purlins which transfer the load to the main trusses. The similarity with Fig. 1 is obvious, the difference being that the slab is curved. Mathematical investigations have proved that owing to the curvature of the slab the actual behaviour of such a system is quite different from what it would appear to be compared with slab construction. The load transmitted by the purlins is only a negligible fraction of the total load and, if certain provisions are made, the purlins are not necessary at all.



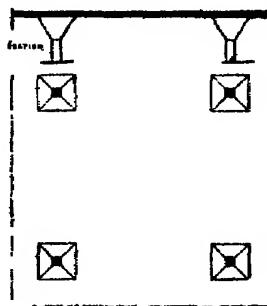
2. The same with a simpler layout of beams.



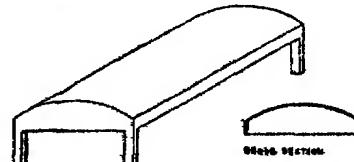
5. Part of a shell vault showing the three components of forces.

The usual arch in stone or brick transmits loads only in the direction of its curvature but cannot carry loads in the direction of the generating line. A concrete barrel vault shell, if properly reinforced, also transmits loads in the direction of the generating line and acts as a beam in this direction. Distributed forces, such as dead-weight, snow and wind, do not produce bending moments in the shell. The equilibrium is maintained by so-called membrane stresses. Fig. 5 shows part of a shell with the three components of forces acting in it. In the usual arch only forces T_2 occur; in a barrel vault shell there are also forces T_1 , (both tension and compression) and shear forces S.

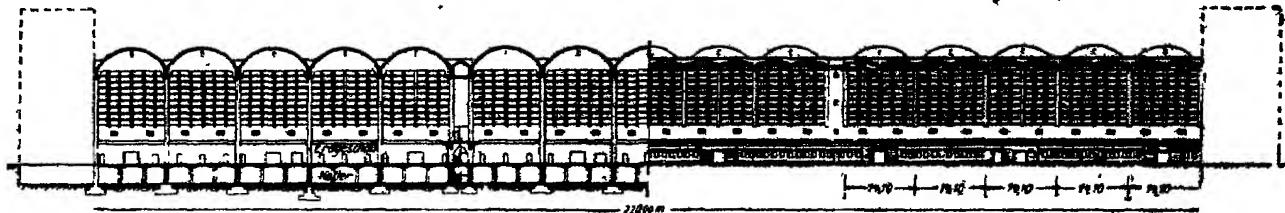
The condition for developing such stresses is the maintenance of the shape of the shell, which is achieved by rigid frames. These frames are connected by members at the springings or edge beams which act as ties (Fig. 6). The whole barrel vault, consisting of the shell, the frames and the edge beams, may be considered as one building unit which is particularly suitable for large span roofs. In the traditional construction the dead-weight of main girders, carrying the secondary members and sheathing, increases rapidly with the span. The main advantage of shell construction is the smallness of the increase in dead-weight required for an increased span, as the roof shell itself acts as load bearing member.



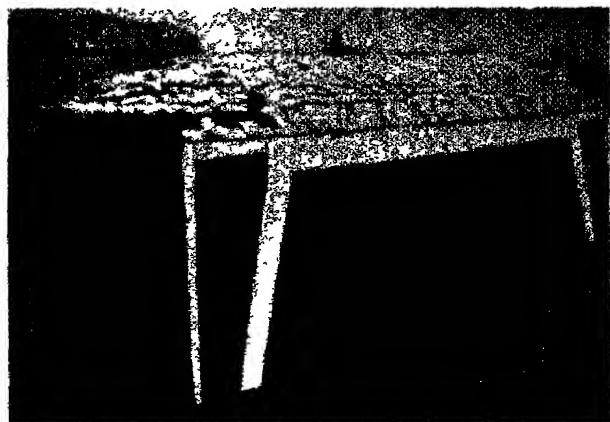
3. Reinforced concrete slabs supported directly on columns.



6. The shell barrel vault with rigid framing ties forming one load-bearing unit.



7. Part section and part elevation of the Market Hall, Frankfurt, which has 15 units of elliptical vaults.



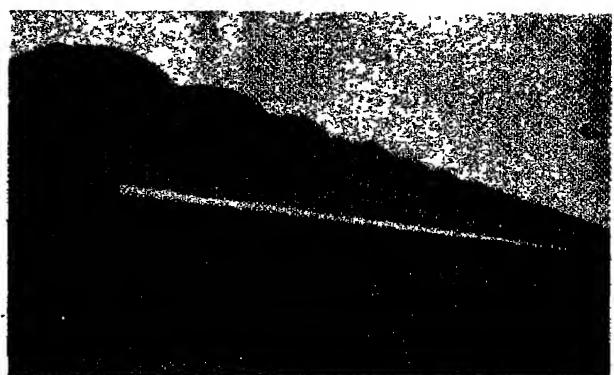
8. Preliminary test model of the Market Hall, Frankfurt, to a 1 : 3 scale.



9. The interior of the Market Hall, Frankfurt.



10. The interior of the Market Hall, Budapest.



11. The exterior of the Market Hall, Budapest.



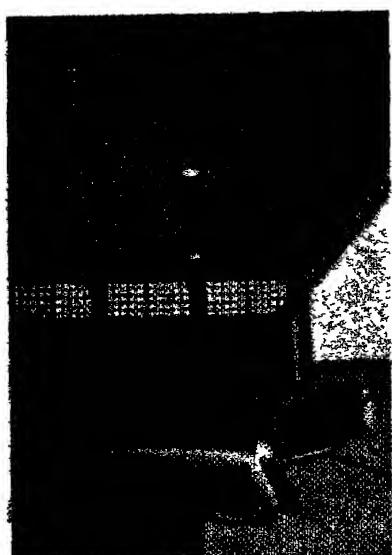
12. A shell roof in Hamburg under construction, showing the reinforcing rods of one of the barrel vaults.



13. Interior of an aircraft hangar, Turin. An example with roof light



14. An aircraft hangar in Germany with an asymmetrical arch.

15. An aircraft hangar at Doncaster Municipal Airport. Each arch spans 30 ft. The length of the barrels is 90 ft. The thickness of the shell is $\frac{1}{2}$ in., which encloses three layers of steel rods.16. A store for salt at Tertre, Belgium. An example of wide span with short length, the span being 144 ft., radius 76 ft. The shell is supported on rigid frames at 30 ft., 16 in. centres, and is only $\frac{1}{2}$ in. thick.

2. Examples.

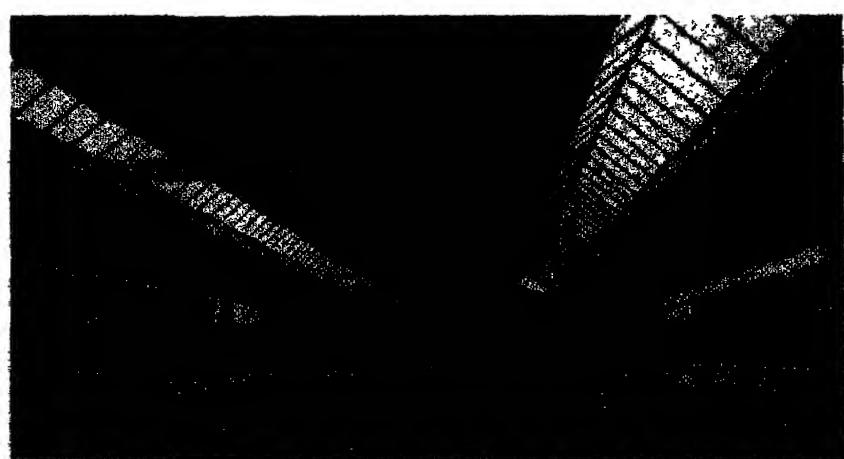
The first application of this system on a large scale was the Market Hall at Frankfurt-on-Main (1927), a hall of 720 ft. length, 141 ft clear span and 75 ft height. The roof consists of 15 units of barrel vaults of elliptical shape and is subdivided by two expansion joints into three parts of five barrel vaults each (Fig. 7). The span of the vaults is 46 ft 3 in., the clear span of the barrels 121 ft and the thickness of the shells in the intermediate span is $\frac{1}{2}$ in. which is $\frac{1}{17}$ of the span (The shells in the end spans are $\frac{3}{4}$ in.) Before the authorities approved the system for such a huge building they asked for a model test. The scale of the model, which was used later as a cycle shed, was 1 : 3 (Fig. 8). The description of the main results of this test gives an idea of the extraordinary strength and stiffness of the system. It should particularly be noted that the thickness of the model

shell was $\frac{1}{15}$ in. The design load was applied nine days after completion and the behaviour of the structure was so favourable that another 50 per cent. of the live load was added on the same day. The maximum deflection in midspan was .054 in. at the edge beam and .133 in. at the crown. The span of the vault was increased by .002 in. The load was removed after ten days and the greater part of the deflection disappeared. At a second test the load was applied on one side only, being increased to 62 lb./sq. ft of horizontal area. The deformations were in line with those at the first test. The usual type of arch construction would have collapsed under such loading on one side only, and this test is perhaps the most convincing evidence of the totally different behaviour of a barrel vault.

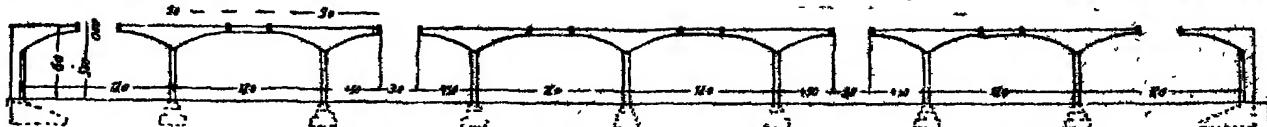
In the last test the load was applied symmetrically until the first fine cracks appeared in the edge beam. This happened at a loading of 197 lb./sq. ft., which is 65 per cent. more than the total design load. At this stage the deflection of the edge beam was $\frac{1}{150}$ of that of the crown $\frac{1}{150}$ of the span (Fig. 8).

Fig. 9 shows part of the inside of the completed building.

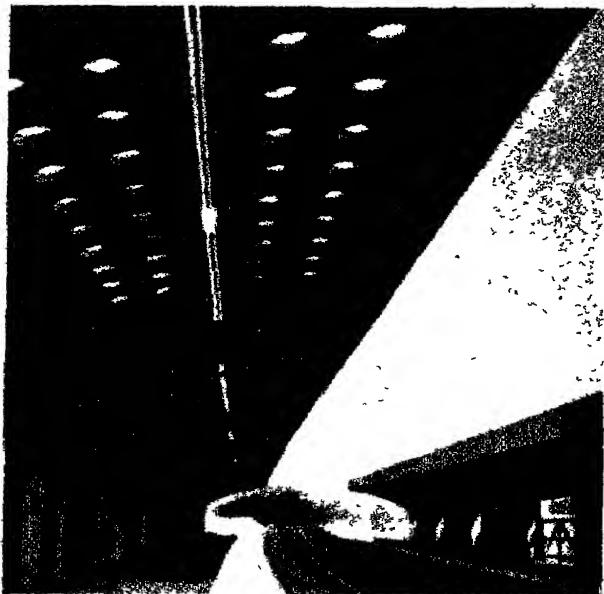
A further development of this type of building is the Market Hall in Budapest (1931). This has a length of 767 ft 8 in. and the span of the barrels is 134 ft. 6 in. The roof is formed by 18 units. The thickness of the shell was reduced to $\frac{1}{3}$ in. This is only $\frac{1}{17}$ of the span. The vault is much flatter than in Frankfurt, which increased the danger of buckling. Further tests were carried out which proved a factor of safety of four for the total load. Since the greater part of the total load is dead load, this factor of safety means that buckling would occur if the assumed load due to snow and wind were increased eleven times. Fig. 10 shows the inside, Fig. 11 the outside of the building. On the latter an application of cantilevered shell construction can be seen which was also tested. The projection of the cantilever from the face of the building is 20 ft.



17. A bus garage at Nürnberg. One column carries a roof area of about 240 sq. yds. Pumice concrete was used here to improve the thermal insulation.



18 Section through the bus garage shown in Fig. 17.



19 Malden Manor Station, on the Southern Railway, is an example of a cantilevered roof in shell construction.

Fig. 12 shows a similar type of roof in Hamburg in course of erection. The arrangement of the reinforcement which follows the trajectories of principal stresses may be seen. The roof light should be noted.

A good example for roof lights is the aircraft hangar at Turin (Fig. 13).

The system is particularly suitable for hangars. A great number have been built in Germany. A specimen with an asymmetrical arch may be seen in Fig 14. The hangar at the municipal airport at Doncaster (Fig 15), built in 1936, is a British example.

The previous examples were all of the type where the span of the arch is small in comparison with the length of



20. A textile factory in Buenos Aires, with roof lights.

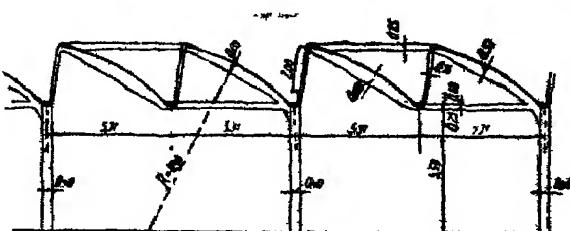
the barrel. In Fig. 16 the relation is reversed. The span of the arch here is 144 ft., its radius is 78 ft. The shell is supported on rigid frames at 30 ft. 6 in. spacings, its thickness is only $\frac{1}{16}$ in. Here again the roof lights are an important feature of the design.

The shell system is well suited for cantilever roofs. An example is shown in Fig. 11. Fig. 17 shows a bus garage at Nurnberg built in this system. The structural arrangement of the building can be seen in Fig. 18. The edge beam which, as is pointed out (p 59) is an essential component of the system, is here on top of the shell, projecting

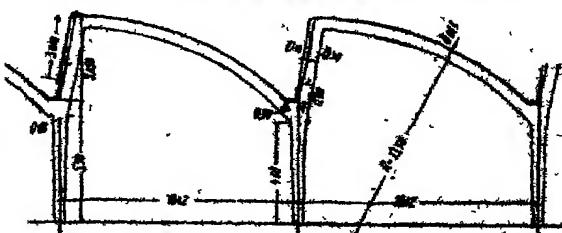
upwards to avoid interference with the light. One column carries a roof area of about 240 sq yds. Pumice concrete of a density of 93 lb. per cu. ft. was used in this structure in order to improve the thermal insulation of the roof and avoid the application of a separate insulating layer. Torsion tests on hollow cylinders had been made before this material was approved.

Good use of cantilever roofs can be made over railway platforms. Fig. 19 is an example.

Factories where a uniform daylight factor is essential provide an important field for the application of shell roofs. Fig 20 shows a textile factory in Buenos Aires, erected in 1932. The dimensions of the framework and the spacing of the columns are shown in Fig. 21. The



21. Part section through the building shown in Fig. 20. The thickness of the shell is 2 in.



23. Part section through the building shown in Fig. 22.



22. A later extension of the factory shown in Figs. 20 and 21. The spacing of the columns was doubled here and the window area reduced by 25 per cent.



24. Another form of shell construction in a similar building in Buenos Aires. The rise of the shell is only 2 ft. on a span of 46 ft. 5 in., its thickness being $2\frac{1}{8}$ in.

thickness of the shell is only 2 in. The area covered is 20,000 sq. yds.

The fire resistance of this shell had a severe test. Eighty tons of cotton which were stored on an area of about 500 sq yds. caught fire, but the damage to the roof was insignificant and was caused mainly by the water used in fighting the fire. Any other roof construction but reinforced concrete would have collapsed under the influence of heat.

The arrangement of two rows of windows in each panel followed that of an existing factory. The light in the new building was better than had been expected. The reflection from the slightly curved roof surface, if this has a bright colour, increases the intensity of light in the room and makes its distribution more uniform.

In a later extension of the factory the spacing of the windows was doubled and their area reduced by 25 per cent. (Figs. 22 and 23)

Fig. 24 shows another form of shell construction in a similar building in Buenos Aires. The overall depth of the shell is only 2 ft. on a span of 46 ft. 5 in., its thickness is $2\frac{1}{8}$ in. An interesting feature of this building is the longitudinal girder which transfers the weight of the barrels to the columns.

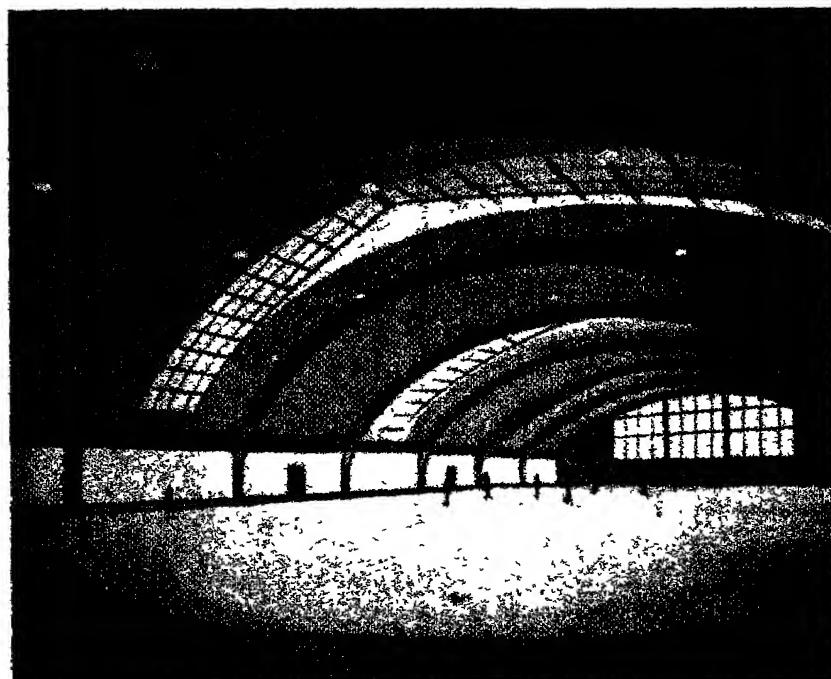
A great number of barrel vaults have been carried out in USA. One famous example is an ice-rink in Haverford (Penn.), accommodating 10,000 visitors (Fig. 25). During the last few years, especially since the war, the system has been used in many factories. Its application is probably the largest building ever built, covering an area of 82 acres, was described in Information Centre No. 1232 (JOURNAL for September 16, 1943, pp. 205-6).

The excellent behaviour of shell construction under fire was also experienced at a military establishment in USA when partly cured concrete shells were subjected to extreme heat

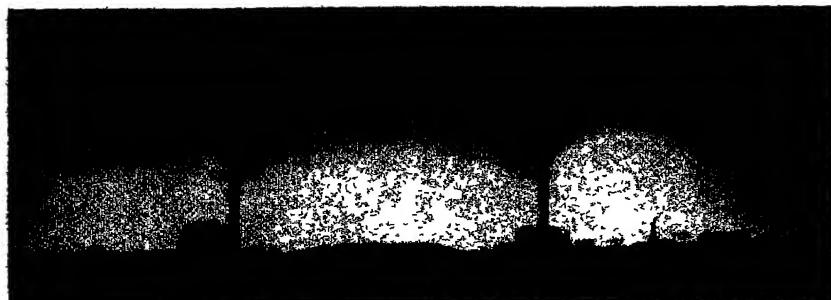
and sudden load changes as the supporting formwork burned away (Fig. 26). The shell roof was supported by concrete columns 50 ft apart longitudinally and 60 ft transversally. The barrels had a thickness of $3\frac{1}{2}$ in. The fire was intense for about one-and-a-half hours and complete loss of at least part of the building was anticipated. Examination showed, however, that the damage was confined to light spalling and minor cracking, which could easily be repaired. About a month after the fire, and before any repairs had been made on the structure, a full-size loading test was performed on one of the damaged roof panels. Under a uniformly distributed load of about 40 lb./sq. ft. the maximum deflection of the barrel was $\frac{1}{100}$ of the span. After removing the load on the second day, a very satisfactory recovery of the shell was observed, proving that the structural soundness had not been impaired by fire.

During the war the system has been used in a number of important buildings in this country. These cannot, however, be described for security reasons—(With acknowledgments to the Architects' Journal)

(To be Continued)



25. The ice-rink at Haverford, Pennsylvania, of shell roof construction with glazing.



26. A building in the USA which showed the excellent behaviour of shell construction under fire.

EXPERIMENTAL SOIL-CEMENT CULVERT

(By Capt. S. S. Cooke-Yarborough, R. E.)

THE problem was to provide a culvert under a new road embankment, in country where stone was not available, and bricks were difficult to get. Previous culverts had been made by using old oil drums, but these had not proved very satisfactory, and a more permanent type of culvert was desired.

Therefore it was decided to try an experimental culvert in Soil Cement. (Fig. 1)



Fig. 1.

The soil was paddy field soil of very fine grains and a mix of 10 per cent of cement (by volume of the finished, compacted, soil cement) was decided upon. The procedure was as follows:—

Firstly the soil which was to form the bottom of the culvert, was dug out 6" deep, broken up—until it all passed a $\frac{1}{2}$ " sieve—and was then thoroughly mixed with the correct amount of cement (Fig. 2). When the mix was of uniform

colour throughout, the moisture content of the mixture was brought up to Optimum Moisture Content (in this case 18 per cent), plus 2 per cent for the hydration of the cement, and the soil-cement was compacted back into place. When compacted thus had formed a soil cement base 5" thick, which was then covered with moist soil for curing.

Next day, the form work was placed (Fig. 3). This consisted of semicircular, corrugated iron sheets, 4'-0" diameter, which were sections from a sectional water tank. These sections were placed on a row of "1 Brick flat in mud mortar" which had been placed on the soil-cement base. The sections were then mud plastered (Fig. 4) to remove the corrugations, and the mud plaster was covered with a tarpaulin to prevent the loss of moisture from the soil-cement mixture.

Rough form work was then placed along the sides and at the ends. The soil-cement was prepared as for the base, (see above) and was placed on the form work. The soil-cement was compacted in 3" layers (Fig. 5) until the crown of the arch had 6" soil-cement cover. This level was maintained over the whole width of the culvert as will be seen from Figs 1 and 7. When the initial set had taken place, the side forms were removed, and the embankment completed. The back-fill along the sides, and the 12" soil cover over the culvert were compacted at Optimum Moisture Content, after which a water-proof surface was applied to the road, and the road was opened to traffic.

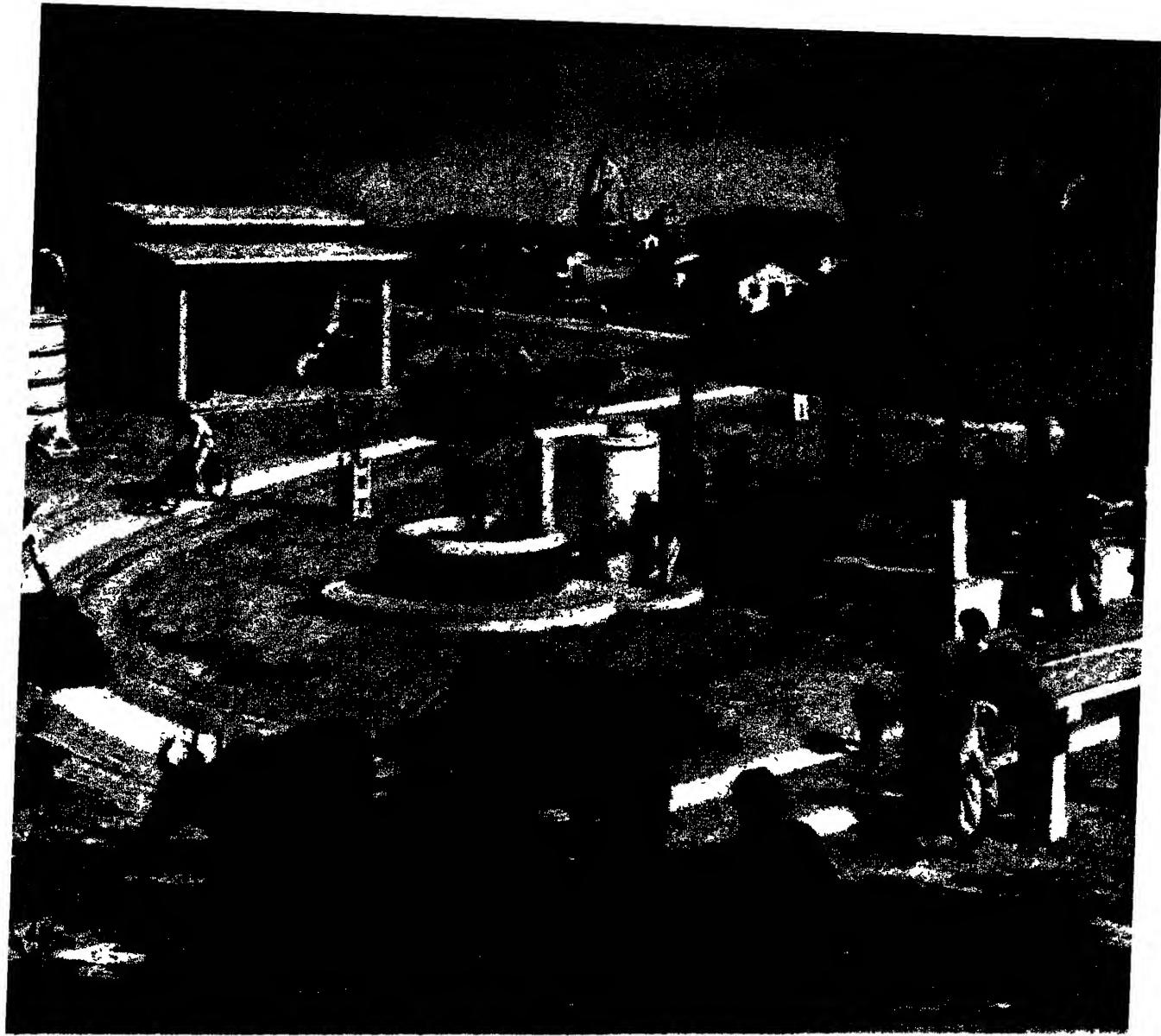
After 14 days the tank sections and tarpaulin were removed, by first cutting



Fig. 2.



Fig. 3.



An artist's impression of the various improvements carried out at Virar.

Cement For Village Improvement Work

A Practical Demonstration At Virar (Near Bombay)

The important role that cement is bound to play in post-war rural planning was practically demonstrated at Virar (38 miles from Bombay) in January 1945 by the Concrete Association of India.

Mr G. F. S. Collins, C.S.I., C.I.E., O.B.E., I.C.S., Adviser to H. E. the Governor of Bombay, inaugurated the various improvements carried out (please see centre spread). The function was attended by a small but distinguished gathering, which included Sir Charles

Bristow, Adviser to the Governor of Bombay, Mr. Bedekar, Collector of Thana, well-known Municipal and P.W.D. officials and other District Local Board members.

Mr. Kynnersley, in a short speech asking Mr. Collins to inaugurate the improvements, said that although planning was the duty of Government, in these days of scarcity of practically everything, it seemed right to help the Government and the people to understand something of the village structures in which cement



A small village house for the returning soldier.

played a prominent part. The work they had done was meant to be of permanent use to villagers in Virar, as well as to serve as an example to other villages.

Mr. Collins, declaring open the amenities, stressed their importance in relation to post-war development schemes. He thanked Mr. Kynnersley and the C.A.I. for having planned road schemes for the Province and now set a 'concrete' example in rural development. He said it was clear that cement must be the most important material for village building in future, and that he would like to emphasise the importance of the Virar experiment and the far-seeing and public-spirited effort of

This concrete fountain will be of immense benefit to the thousands of visitors to Virar every week on

DETAILS OF IT CARRIED

1. A new village house incorporating jalli work, ventilators, sun shade.
2. A permanent concrete grain silo.
3. Improvements to the District Library.
4. A demonstration length of village roads.
5. A demonstration length of a single single-wheeled bullock-carts.
6. Clean and hygienic platforms to the railway station.
7. Concreting verandah and one room of a new drinking fountain.
8. Surface drains.
9. Athanis (rests for head-loads), c



CEMENT WORK AT VIRAR.

These features such as roofing, flooring, the house, for storing grain, all, the approachway, and construction or bullock-cart wheel tracks. Concrete, 2 ft. wide, for use by bicycles, etc during all weathers. market sheds. masala. blocks, lamp standards, etc.



A view of the 400 ft. concrete road near the market-place.



the Cement Marketing Co of India, Ltd (Full text of Mr. Collins' address was published in our February issue)

Mr. H. G. Vartak, Chairman of the Virar Village Panchayat, thanked Mr. Collins and the distinguished visitors and expressed the gratefulness of the people of Virar to the Cement Marketing Co of India, Ltd., for their magnificent gift in the form of these concrete improvements.

Details of the various improvements carried out are given in a little booklet entitled "Dawn of the New Era" which can be had from the C.M.I. Publicity Department, 20, Hamam Street, Bombay, by sending postage stamps worth As 2

A close-up of the single track in concrete—the post-war cycleway of India. Details of these tracks and the types of vehicles using them have already been published in our March issue

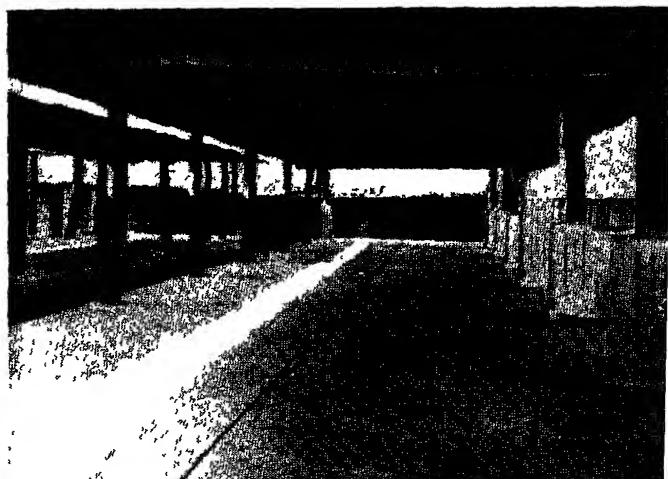


TOP: Close-up of the grain Silo, built of precast reinforced concrete rings

BOTTOM (Right). Mr Kynnersley welcoming the guests Seated on the dais from L to R are: Mr H G Vartak, President of Virar Panchayat, Sir Charles Bristow and Mr G F S Collins Advisers to H E the Governor of Bombay, Mr Kynnersley, Mr C W Fowler, Managing Director of the Cement Marketing Co of India, Ltd., and Mr G V Bedekar, Collector of Thana

BOTTOM (Left) A view of the gathering. The front row includes Mr U. M. Mirchandani, Municipal Commissioner, Mr Jamnadas Dwarkadas, Mr N V Modak, City Engineer and Mr E A Nadusah, Hydraulic Engineer, Bombay Municipality

A close-up of the Market platforms paved with Concrete. The wooden pillars have been provided with concrete surrounds



The 'Athani' or rest for head-loads near the market





Fig. 4.



Fig. 5.

away the row of bricks. The ends of the culvert were then finished with permanent wing walls.

Soil-cement remains stable when saturated, though its strength is reduced. Therefore if the inside of the culvert is given a paint coat of Bitumen to waterproof it, a smaller percentage of cement may be used in the mix, but on no account should the bitumen be applied until the soil-cement is thoroughly dry.

The proportion of cement required in the mix will vary with each type of soil, being least in a sandy, well graded

soil. Soils with high shrinkage are not suitable for this work. The correct mix must be found by making trial samples from the soil to be used, and comparing the results. After a little experience in this work, it will be found that for a small job such as a culvert, a satisfactory mix can be decided upon after a visual examination of the soil.

It should be noticed that compaction is best carried out with "sheep's foot" tamper (Fig. 6) which compact from the bottom up, thus ensuring the maximum density in the compacted soil-cement.

If the wing walls are built before the placing of the soil-cement over the arch, this will do away with end shuttering,

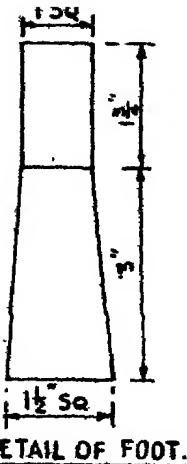


Fig. 6.

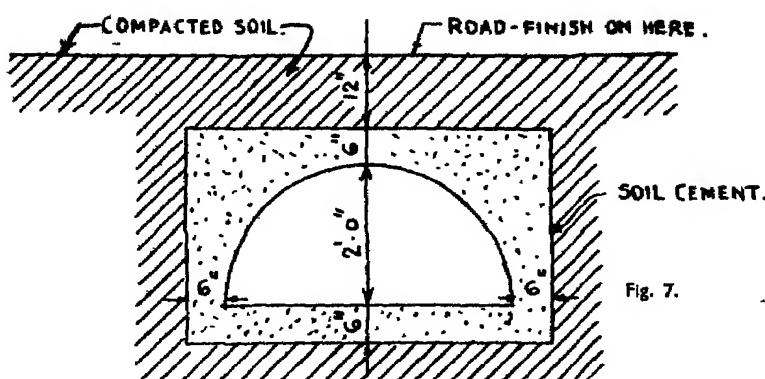


Fig. 7.

and will ensure a close joint between soil-cement and wing wall (Fig. 1) shows the finished culvert before construction of the wing walls.

It is felt that with a careful approach to the problem, satisfactory culverts could be economically constructed in many districts, where the scarcity of stone or bricks makes culverts expensive.

By using soil-cement for the construction, only cement has to be transported to the site, thus saving the cost and haulage of sand and aggregate, or bricks. As this will cause a very considerable reduction in costs it is felt that this method of culvert construction is deserving of further experiment and use.

CONTINUOUS CONCRETE GIRDER BRIDGE

By C. N. CROCKER*

THE largest reinforced concrete continuous girder bridge in Georgia has recently been completed over the Chattahoochee River near Atlanta, U.S.A. The structure is located in a new access highway serving a large airplane plant a few miles distant from Atlanta. The new route parallels existing U.S. 41 which, at this point, spans the Chattahoochee by means of an old truss bridge now rapidly nearing obsolescence. Need for a new bridge at this location has been felt for some time and, with the coming of the airplane plant, it became a wartime necessity.

Only the main river spans are of continuous girder type, the central span being 90 ft in length and the two end spans each 65 ft long. Approaches are simple T-girder concrete spans, six on each side of the continuous girder river spans, making a total length of 701 ft. 8 in.

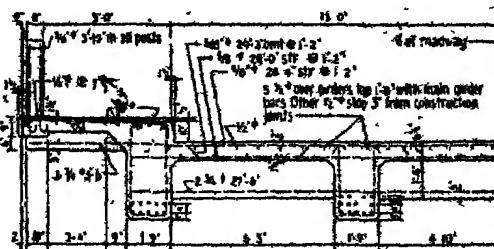
In the past, our bridge designs for such locations would have called for structural steel. A number of such structures have been built throughout the State using continuous rolled, wide-flange beams with concrete decks. On account of the need to save critical materials this structure was designed in reinforced concrete using long-span continuous girders. Spans of similar type but of shorter length have been previously designed and constructed. The State Highway Department of Georgia has given considerable study to continuous concrete slab bridges composed of short spans. Standard plans have been prepared for this type, involving three and four-span layouts, and some are under construction at the present time.

The design of the Chattahoochee River Bridge is based on an H-20 loading with $f_s = 22,000 \text{ psi}$, and $f_c = 1,000 \text{ psi}$, in accordance with government regulations. Design followed the usual proce-

dure for continuous girder bridges.[†] The roadway is 26 ft. between kerbs, with a 6 ft. wide sidewalk cantilevered from one side. There are four main girders spaced at 8 ft. 2 in on centres, the width of girder stems being 21 in. Deck slab is 8 $\frac{1}{2}$ in thick. The soffit of the girder is parabolic in shape, with depths varying from 3 ft. 7 in. at the centre to 9 ft. at the interior supports. These dimensions include the thickness of the deck slab the girders are freely supported on concrete piers, and are fixed against sliding at one interior pier.

No claims are made as to the relative economy of this type of construction as compared to others. It would require much broader experience during normal times to establish this information.

The contract for the bridge was let in the fall of 1942 at a price of 201,466 dols. This is somewhat higher than bridges of this size have normally cost in past years. Analysis of the bid, however, indicates that inflated costs of labour and materials,



SECTION A-A

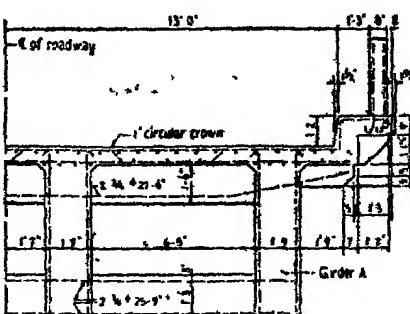
due to wartime conditions, had considerable bearing on the bid prices. Another factor influencing the cost may have been the fact that flood conditions on the Chattahoochee River are rather hazardous and frequent high water could be anticipated during the construction period.

This particular type of structure harmonises with the surrounding landscape and produces unusually attractive and sturdy appearance. Economical maintenance is anticipated and, after it has served its wartime use, the bridge will take an important place in the State highway system.

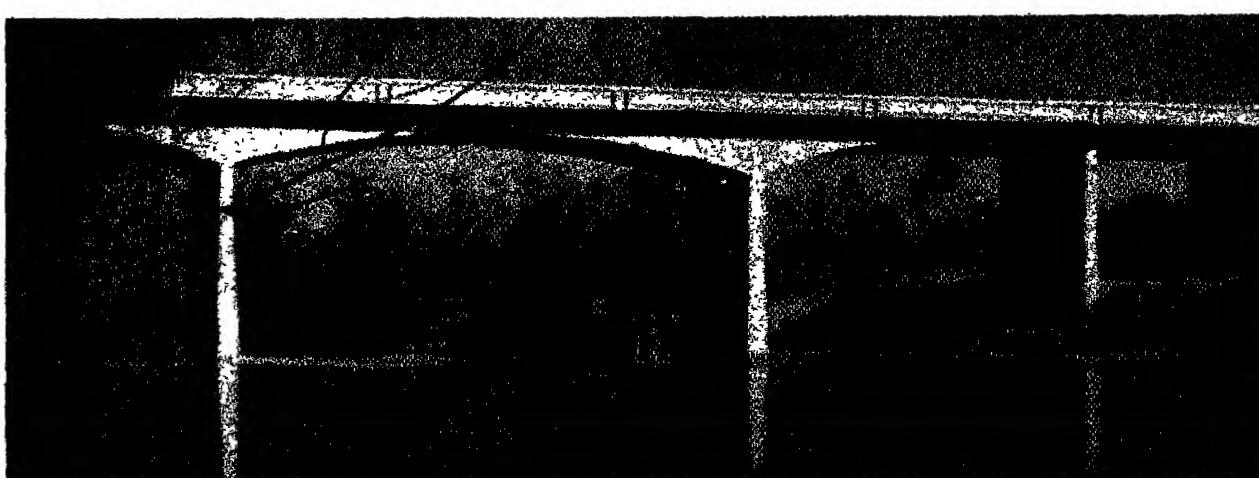
The bridge was designed by the Bridge Department of the State Highway Department of Georgia under the supervision of the writer and under the general direction of M.L. Shadburn, former state highway engineer. G. L. Strickler, of Austell, Ga., was the contractor.—[With acknowledgments to "Constructional Review."]

* Bridge Engineer, State Highway Department of Georgia.

† Continuous Concrete Bridges, published by Portland Cement Association and available for perusal in the library of The Australian Cement Manufacturers' Association.

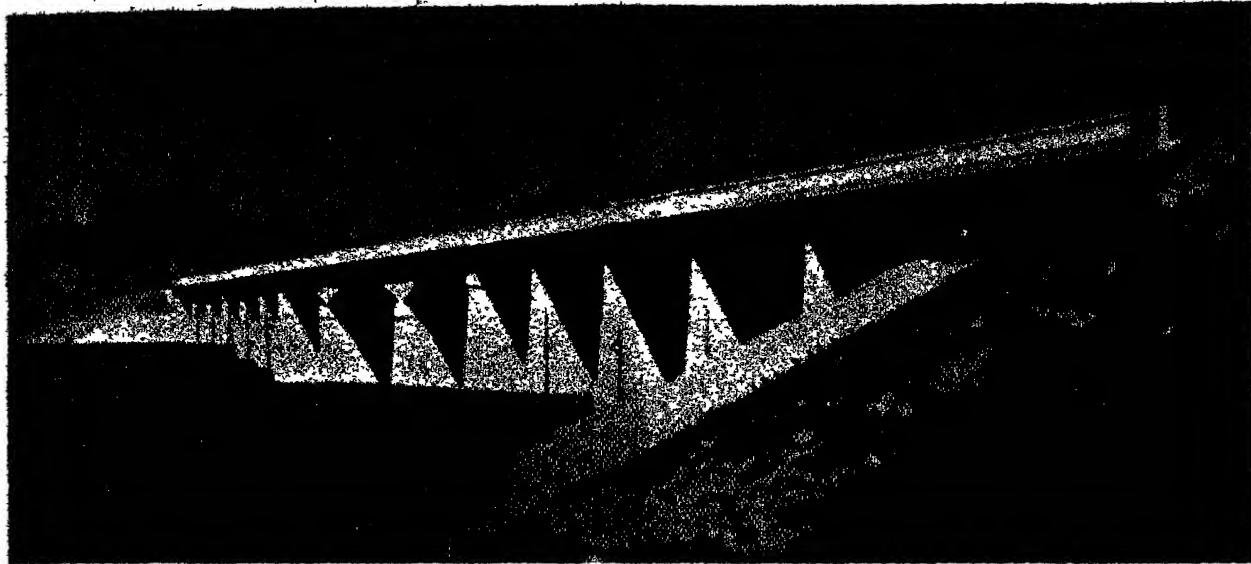


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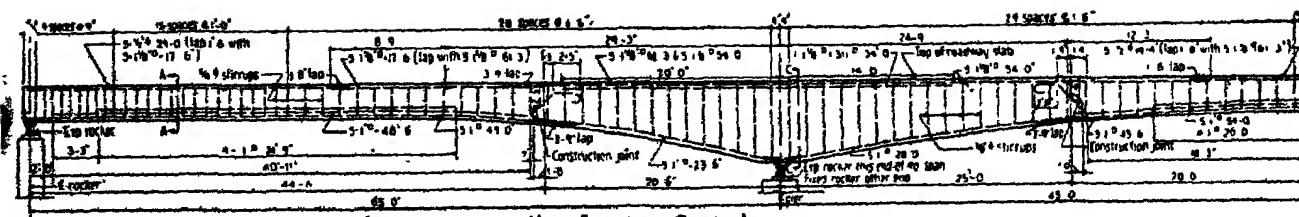


CONTINUOUS CONCRETE BRIDGE, CHATTAHOOCHEE RIVER, ATLANTA, U.S.A.

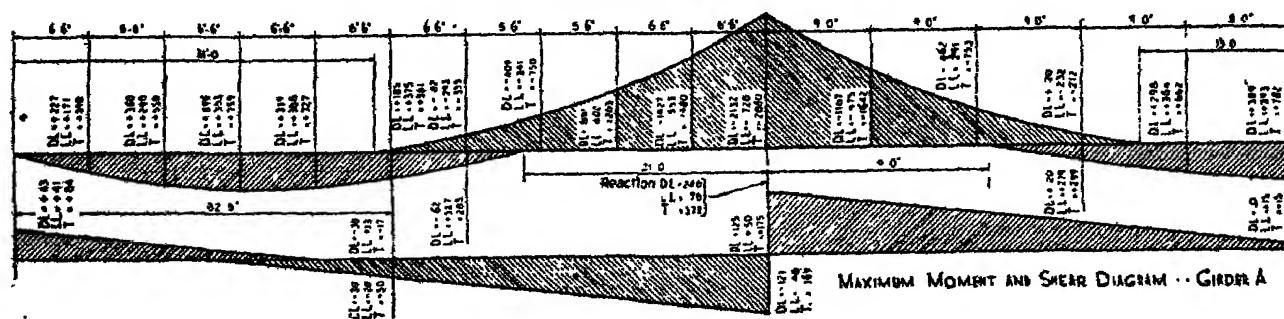
This new Bridge over the Chattahoochee River consists of a three-span continuous concrete girder unit over the river and 12 simple T-girder-concrete approach spans. The bridge is located on an important access highway to a war plant. The bridge provides a 26 ft. roadway supported on four girders 2 in. wide. The deck is anchored against sliding at one of the interior piers.



BRIDGE OVER CHATTAHOOCHEE RIVER, NEAR ATLANTA, U.S.A.



HALF ELEVATION GIRDERS A



MAXIMUM MOMENT AND SHEAR DIAGRAM - GIRDERS A

CONTRIBUTIONS

Articles and photographs suitable for publication in *The Indian Concrete Journal* are always welcome, and those that are accepted, will be paid for at our standard rates.

SOME NOTES ON GUNTING

Definitions

Gunite is a trade name designating mixtures of Portland cement, fine aggregates and water placed by a portable pneumatic device known as Cement Gun.

Operating Requirements

From 60 to 225 cu ft of free air per minute at a minimum pressure of between 30 and 60 lb. per sq. in. in the chamber is necessary, depending on size of gun. Water under a pressure at least 15 lb in excess of air pressure is also required. Pressure requirements increase with height of operation above gun.

Mixtures

For ordinary purposes one part, by volume, of cement to three parts sand is used. Richer mixes are not recommended except under special conditions. Mixes not leaner than one to four can be used where strength and impermeability requirements of the work permit, such as for dry interior work.

Materials are ordinarily hand mixed and passed through a $\frac{3}{4}$ to $\frac{1}{4}$ in sieve to remove lumps or oversize particles before being placed in the gun.

Operating Range

The gun operates best with a hose length of from 50 to 150 ft, though it can be used over horizontal distances up to 450 ft and vertically up to about 250 ft. Higher pressures are required when operating over 100 ft from the gun. On large jobs where exceptionally rapid applications are possible and desirable for economy, a higher pressure is required.

Control of Consistency

Quantity of water is controlled within certain limits by a valve at the nozzle. Proper consistency is usually determined by the operator. Low water ratio is required under ordinary conditions. Too wet a mix will sag, or fall, from vertical or inclined surfaces or separate in horizontal work, while too dry a mix will not properly adhere. Atmospheric conditions may affect water requirements, but ordinarily it will not exceed 3 to $3\frac{1}{2}$ gal per bag of cement, including moisture in sand, depending on mix used and characteristics of aggregates.

Process of Application

Usually the nozzle is held perpendicular to the surface to which Gunite is applied, the nozzle being held 3 to 4 ft from the surface and moved in a narrow range to produce a spreading effect over a small area.

On vertical surfaces, the limit of the thickness which can be built is reached when the material starts to sag or separate (generally from 1 to $1\frac{1}{2}$ in.) On horizontal surfaces, except overhead, depth is a factor of plasticity, and the limit is reached when material starts to spatter or show other evidence of too much moisture. On overhead surfaces the limiting thickness of a layer is about 1 in. Rapid placement reduces the thickness which may be built in a single layer. The longer the interval between applications made while the first material is still plastic, the greater the thickness which can be applied without separation.

With proper manipulation almost any thickness of slab may be built, the bond between layers being strong if each preceding layer is washed and cleaned with a water and air blast.

Precautions in Operation

The original surface, and each surface which is permitted to harden before applying succeeding layers, should be washed with water and air blast, or a "stiff" hose stream, and loosened material removed.

Sand which rebounds and does not fall clear of the work, or which collects on horizontal surfaces, must be blown off from time to time to avoid leaving sand pockets in the slab.

Surfaces to be gunited must be thoroughly cleaned of all dirt, oil or foreign matter and all loose or weakened material removed. Rust scales, paint or deteriorated materials seriously weaken the bond. Preliminary sand-blasting will improve the bond.

Gunite should never be applied to a surface containing frost or ice. Such surfaces must be heated until frost is removed.

Where standing or running water is encountered the water must be removed before Gunite is applied.

Some positive means of checking the thickness of application is usually necessary.

Moist curing is essential. Duration of curing should be the same as for concrete.

Protection from freezing or quick drying must be provided. Quick drying promotes cracking due to shrinkage.

Reinforcement will be most firmly embedded if Gunite is shot under it alternately from both sides.

On exposed surface not subject to fire hazard a minimum of $\frac{1}{2}$ in. of Gunite should be provided over reinforcement, where subject to fire hazard, a minimum cover of $1\frac{1}{2}$ in. is recommended.

Suspended members, like beam soffits, should be built up slowly in layers not over one inch thick.

Insufficient air or water pressures adversely affect quality and output.

Material which rebounds is seldom sufficiently well graded to be re-used.

An experienced and careful operator or nozzle man is essential to a satisfactory job.

Physical Properties

When properly made and applied, Gunite is extremely strong, dense concrete highly resistant to weathering and many forms of chemical attack. It is heat resistive to a high degree, and may be made more so by substituting granular or other refractory aggregate for part or all of the sand. Absorption is low, making it an excellent waterproofing medium. Resistance to abrasion is comparable to that of good quality concrete made from similar aggregates. The bond to other Gunite or well cleaned, hardened concrete is excellent and is satisfactory on many other materials of entirely different characteristics or composition.

Tests

Tests show Gunite follows the water-cement ratio strength relationship. Compared with hand-placed mortar or plaster, Gunite of equivalent aggregate proportions usually possesses decided advantage of strength because it permits placement with low water-cement ratios.

Design

Load tests on slabs show Gunite conforms to the same design assumptions as ordinary concrete of equivalent compressive strength.

It is good practice to reinforce all work in exposed structures with at least 0.4 per cent of steel in both directions.

CAPACITIES OF GUNS.

Type	Free Air Required Cu. Ft.	Pressure Per Min.	Capacity Av. Sq. Ft. Per Sq. in. 1 in Thick Per 8-hr. Shift
N-oo	60	35-50	600
N-o	100	35-50	900
N-1	175	35-50	1300
N-2	225	40-60	1800

APPROXIMATE COVERAGE PER BAG OF CEMENT.

Proportions

Horizontal Area Covered, Sq. Ft.
Thickness

Cement 1 bag	Sand $2\frac{1}{2}$ cu. ft.	$\frac{1}{2}$ in.	1 in.	2 in.	3 in.	$4\frac{1}{2}$ in.
			18	10	6	30
	3 cu. ft.	40	22	11	8	34
	4 cu. ft.	50	28	14	10	40

Vertical Area Covered, Sq. Ft.
Thickness

$\frac{1}{2}$ in.	1 in.	2 in.	$4\frac{1}{2}$ in.
19	9	4	
20	10	7	
24	12	9	

Approximate Capacities

Capacities of guns shown in accompanying tables represent average conditions. Where several layers are placed, coverage will vary. Type of work also affects average daily coverage.

General Specifications

Note: The following specifications are typical only and should be amplified to meet the requirements of the job

1. Fine aggregate shall consist of washed sand, and shall be hard, dense, durable, clean, sharp and graded evenly from fine to coarse, with no particles larger than $\frac{1}{2}$ in. in diameter. It shall be free from organic matter and shall not contain more than 5 per cent. by weight of loam or clay.

2. "Dry," as applied to the sand to be used, means that it shall contain not more than 6 per cent. nor less than 3 per cent. of moisture.

3. Before placing mixture in hopper of Cement Gun, all material over $\frac{1}{2}$ in. shall be removed.

4. For lengths of hose under 100 ft., pneumatic pressure at gun shall be 30 lb. or more. Where length exceeds 100 ft., increase of pressure shall be required to maintain nozzle velocity equivalent to that obtained by 30 lb. pressure at gun with 100 ft. of hose. Steady pressure must be maintained.

5. Water used for hydration at the nozzle shall be fit for drinking and shall be maintained at a uniform pressure which shall be at least 15 lb. above pressure of air used, but not less than 60 lb. per sq. in.

6. At any construction joint, Gunite shall be sloped to a thin edge. Before shooting adjacent section, sloped portion shall be thoroughly cleaned and wetted. No square joints will be allowed.

7. Gunite shall be damp cured at least seven days after placing. No Gunite shall be placed during freezing weather except when proper protective measures are taken as with ordinary concrete work. Gunite shall not be placed against frosted surfaces.

Fireproofing Steel Members

1. Gunite for fireproofing shall be 1 part Portland cement and 3 parts sand.

2. Steel shall be cleaned of paint, rust-scale, grease or other material before Gunite is applied. Beam and column cagings shall be galvanized. Such reinforcement shall be welded fabric of No. 12 wire spaced 2 in. in each direction, or No. 10 wire spaced 3 in. in each direction, or it may be expanded metal having not less than a 2 in. opening. Cagings shall be secured to steel members through holes on approximately 3 ft. centres. In placing the mesh, rods not less than $\frac{1}{2}$ in. in diameter shall be fastened to the steel member. Mesh shall then be securely tied outside these rods with wires spaced at 12 in. intervals. Mesh shall be held $\frac{1}{2}$ in. from face of steel. Adjacent sheets of reinforcement shall lap not less than 4 in.

3. Gunite encasement on columns and girders shall follow out line of

members and shall have thickness not less than 2 in., except webs of girders not subject to fire hazard, and in special cases of secondary floor beams between girders, which shall have a covering of $1\frac{1}{2}$ in.

Floor and Roof Slabs

1. Gunite for floor and roof slabs shall be 1 part Portland cement and 3 parts sand.

2. Reinforcing mesh shall be galvanized and shall have a sufficient cross sectional area to carry static and impact loads, to which slab may be subject. Adjacent sheets of reinforcement shall have a side and end lap of one mesh and shall be securely held in position so as to be no nearer than $\frac{1}{2}$ in. to any exposed surface.

3. Slabs may be shot in two or more layers, depending on thickness. Final coat shall have thickness of approximately $\frac{1}{2}$ in. placed against straightened and thoroughly cleaned and wetted surface of layer already in place, and shall be finished by floating, trowelling or brushing as required.

Building Walls

1. Gunite for wall shall be 1 part Portland cement and 4 parts sand.

2. Wall thickness shall not be less than $1\frac{1}{2}$ in. for spans up to 4 ft., and 2 in. for spans up to 7 ft.

3. Mesh reinforcement shall be galvanized, welded wire fabric, with wire spaced not more than 3 in. apart in each direction, or galvanized expanded metal with openings not more than $2\frac{1}{2} \times 6$ in. The cross sectional area per foot of mesh in each direction shall be not less than 0.4 of 1 per cent. of cross sectional area per foot of wall.

4. Where Gunite is applied to structural steel framework, reinforcement shall be secured to $\frac{1}{2}$ in. diameter rods fastened to steel framework at intervals of not more than 18 in. Mesh shall be wired to rods with No. 14 black annealed wire at 12 in. intervals, and shall be furred out not less than $\frac{1}{2}$ in. from the face of structural steel members.

5. If framework of building is concrete, No. 10 gauge annealed wire loops shall be set in concrete every 18 in. along face of all members. Reinforcing mesh shall be fastened by twisting ends of those wires about mesh, taking care to fur mesh out of least $\frac{1}{2}$ in. from concrete surface.

6. Reinforcing mesh shall be carefully beat to fit around corners and in re-entrant angles, and shall in no place be sprung into place. All laps shall be firmly tied together at intervals not exceeding 18 in. Additional reinforcement shall be placed diagonally across corners of all openings. Such strips shall be at least 9 in. wide by 24 in. long and shall be securely wired to main sheets of reinforcement.

7. A permanent or temporary backing of tarred felt, metal or wooden panels shall be placed and properly secured to give required thickness of Gunite when wall is completed.

8. Gunite shall be shot over reinforcing mesh and backing in one or more layers to within approximately $\frac{1}{2}$ in. of finished surface of completed wall. This surface shall then be rodded to true lines by using a flat, steel-edged screed, a trowel, or other sharp cutting edge. Final coat shall be shot in place after preceding coat has been thoroughly wetted and washed down with compressed air and water. Finish coat may be treated with a brush coat or by trowelling.

9. Where double walls are required, the two slabs shall be connected at intervals with solid studs shot as an integral part of the slabs, and these studs reinforced with vertical rods.

Covering for Brick, Tile or Old Concrete Walls

1. Gunite shall be 1 part Portland cement and 3 parts sand.

2. Surface to be covered shall be thoroughly cleaned and washed down with water and compressed air and all loose material removed.

3. Foundation coat shall be not less than $\frac{1}{2}$ in. thick, and after being carefully rodded with a sharp steel-edged screed or trowel, and thoroughly wetted, shall be followed by finish coat and not less than $\frac{1}{2}$ in. thick. Finish coat shall be treated with a brush coat or by trowelling.

Reservoir Linings

1. Gunite shall be 1 part Portland cement and 3 parts sand.

2. Surface against which Gunite is placed shall be thoroughly cleaned, care being taken to remove vegetable matter and dirt from surface and open joints. Entire surface shall be washed down before Gunite is shot in place.

3. Cross sectional area of reinforcement shall be at least 0.4 of 1 per cent. of cross sectional area of lining in each direction. Openings between wires of mesh shall not be greater than 4 in., and there shall be a lap alongside of sheets of not less than 4 in. and at ends of sheets of not less than 6 in., all laps to be securely tied together with wires at close intervals. Reinforcement shall be securely fastened to surface by means of anchors not more than 3 ft. apart in both directions.

4. Gunite covering shall have a thickness of from 2 in. to $2\frac{1}{2}$ in., depending on conditions encountered.

5. Gunite shall be applied in bands or strips to form a compact, durable covering of the thickness required, and shall be free from undue humps and depressions. Surface shall be left with natural finish, true to line. All corners and angles shall be sharply defined.

6. Particular care shall be given to formation of construction joints. They shall be sloped to a thin edge and the edge shall be thoroughly wetted before adjacent section is shot. No square joints will be allowed.—(With acknowledgments to Portland Cement Association of America.)

PRECAST CONCRETE BRIDGE CONSTRUCTION

By L. J. EICHELGRUN.

THE following notes describe the use of precast concrete for bridge construction. Most of the examples record bridgework built or designed for the Great Western Railway.

New Decks in Existing Bridges.

Fig. 1 shows the redecking of an underbridge with precast concrete slabs. The example shows that a refuge for gangers could be easily provided by extending the width of the two middle slabs. The existing bridge girders have protruding rivet heads, and packings are needed to give a level support for the slabs. It is not desirable to use a layer of 1-in. or 2-in. cement mortar, because such a thin layer tends to crack. The section shows hard-wood strips placed between the rivet heads, the latter being covered with cement mortar to prevent corrosion.

The old decking generally consists of 3-in. to 4-in. timbers or rolled steel sections, and the new concrete slabs must be kept to a minimum structural thickness to prevent an undue increase of the dead weight. Excessive raising of the rail or road level must be avoided, as this may involve earthwork on the adjoining embankments. The restriction of the structural thickness of the new deck slab often necessitates a high percentage of reinforcement. Standard slabs are used wherever possible.

(With acknowledgments to "Concrete & Constructional Engineering.")

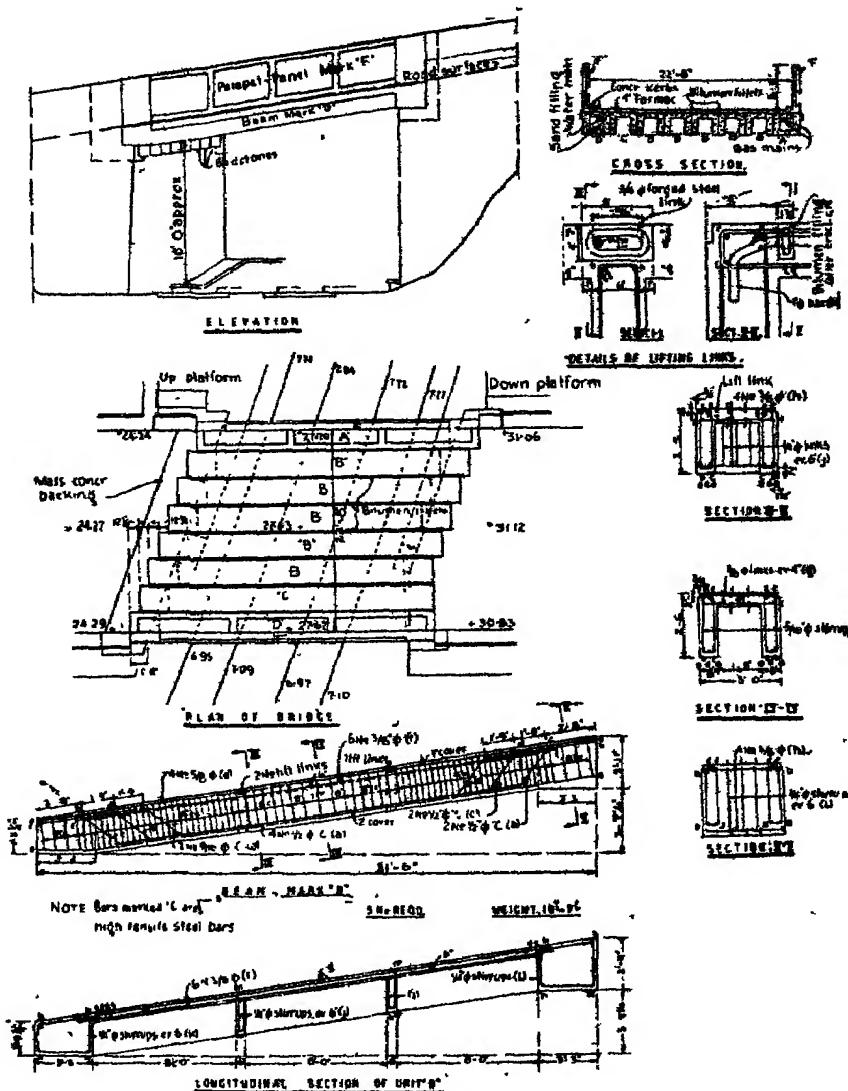
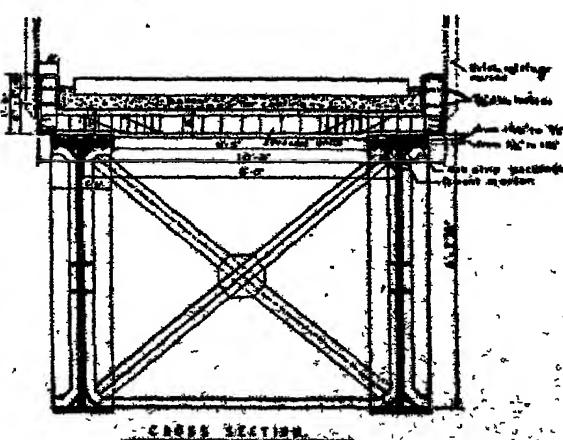
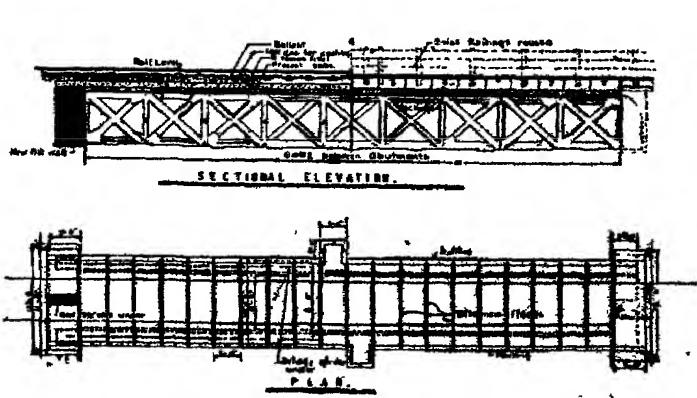


FIG. 2.



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May 15th, 1945

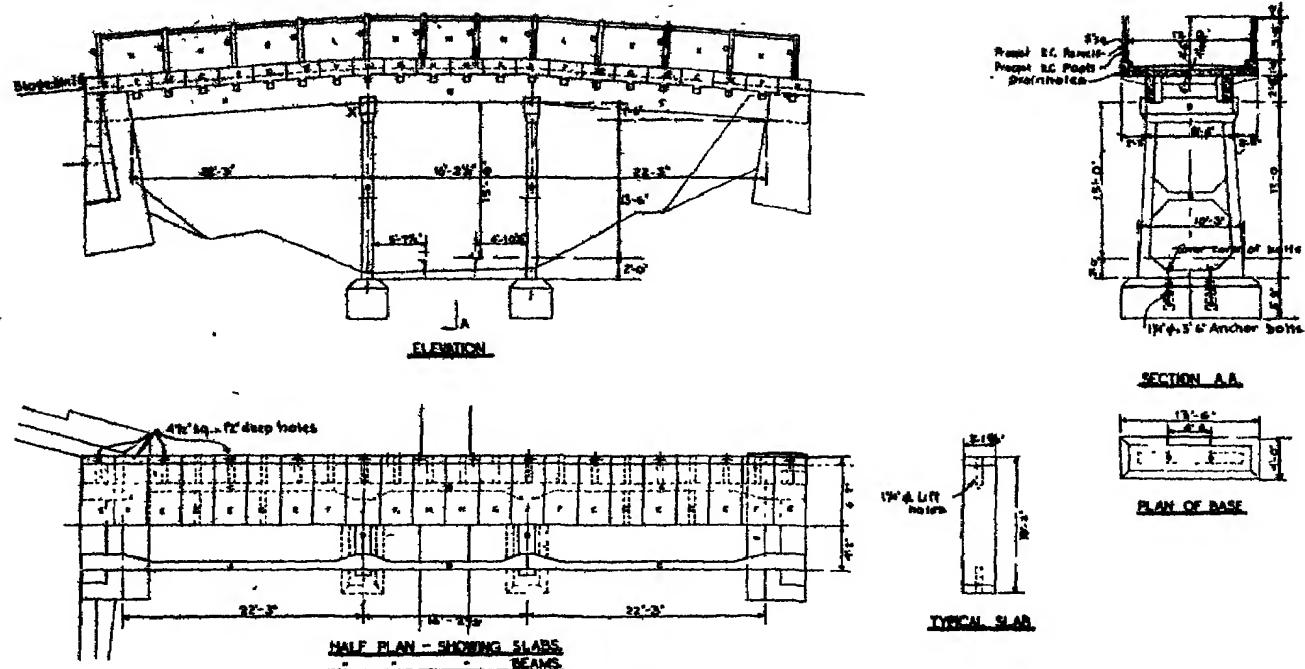


Fig. 3.

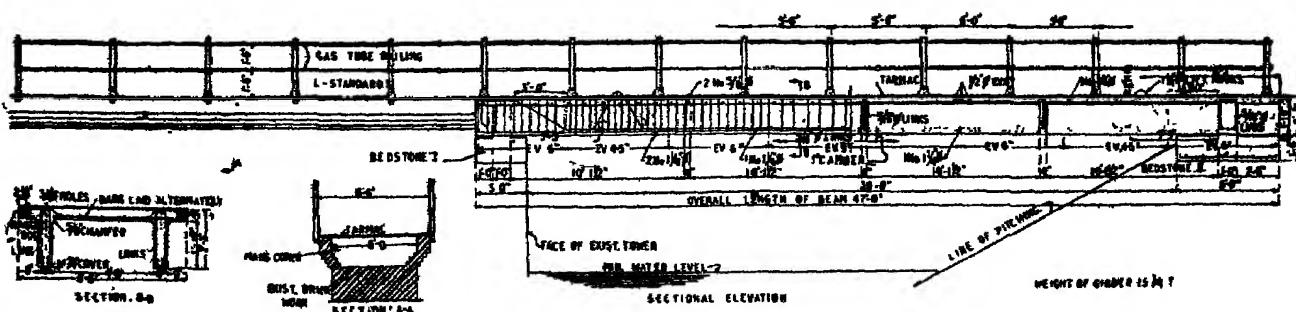


Fig. 4.



Fig. 5.

NOTE ON CEMENT CONCRETE ROADS

[We publish this idea for its originality and challenge to accepted designs and invite comments from our readers—Editor.]

To: THE EDITOR,
THE INDIAN CONCRETE JOURNAL.

IN recent years the construction of cement concrete roads has made a phenomenal progress both as regards its universal use as well as its technique. The new method has completely ousted the older one, which was invented by Telford and Macdame over a hundred and fifty years ago. Because of the growing use of vehicles, both in peace and war times, the wear and tear of roads became great. Necessity being the mother of invention, cement concrete roads came into existence.

Present Method —At present cement concrete roads are constructed in small blocks. The joints between these blocks are filled with Bitumen product to make allowance for expansion. Each block is a separate unit. In my opinion the use of Bitumen can be dispensed with.

My Device —In my method the roads should not be constructed in separate blocks but as a complete whole. Neither should Bitumen be used in expansion joints. This can be done in the following way: Suppose the cement concrete slab of the road is 4 inches thick, in the lower half of its thickness, cuts of $\frac{1}{2}$ inch width should be made crosswise along the whole width of the road; while similar cuts of $\frac{1}{2}$ inch be made at uniform but alternating distances on the upper half. This point will become clear with the help of the accompanying sketch. The idea of alternating cuts is

that the counteracting movements due to temperature in the bottom and top half will prevent any possibility of cracks appearing on the surface. At the same time the whole road is one uniform slab instead of numerous small slabs. Arrow marks in the sketch below show the counteracting movements because of expansion.

Method of Construction —To begin with soft wooden ribs of $\frac{1}{2}$ inch thick and 2 inches depth should be adjusted at uniform distance of 8 or 10 feet crosswise along the length of the road. These wooden ribs are not to be removed and shall be left in that position. Soft wood pieces shall act as cuts for the lower half of the road. For the upper half flat iron pieces of $\frac{1}{2}$ inch shall be adjusted as it was done in the case of wood ones. But unlike the lower half these iron pieces are removed as soon as concrete shows signs of setting, and thus the same can be used again for further construction. The wooden ribs placed in the bottom half will be ravaged by time but so long they are intact, being soft, they can be easily compressed by the expanding concrete. The surface cuts will get filled with dust etc., and if necessary can be filled with fine substance. The sign of cuts is negligible and cannot hinder the traffic in any way, if left unfilled. It may be remembered that full depth of concrete should be filled in one mass and not in two layers. The dividing line between the two halves (shown by dots) in the accompanying sketch is only imaginary. It

merely denotes the movement action of concrete at bottom and top halves.

Horizontal Cuts :—In case horizontal cuts are required because of the great width of the road, they should be made at suitable distances. Such grooves should be made in the upper half only, because expansion at the bottom half of the road is negligible.

How to End the Day's Work :—Pieces of metal should be used as connecting link between two day's work. Every evening the end of whole width of the road must be slightly battering and not made in a flat slope, so that the next day's work does not overlap on top of it like a knife edge. On the end of the day's finished work, uncoated stone metal should be inlaid in such a way that cement does not cover those pieces completely. All short edges of metal should be projected outward. While commencing the work again, the uncovered ends of metal should be washed, which will thus get interlocked with the previous work, and shall not either crack or separate at these joints.

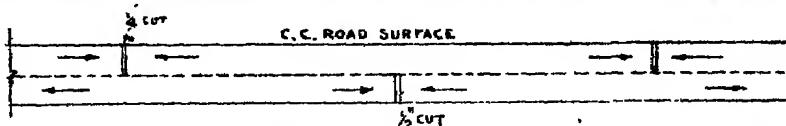
Conclusion —I have tried to state my method as briefly as possible. Use of technical terms has been avoided to make it intelligible for the layman. I am sure that my method will prove no only more economical but also more effective. It will make the road no a series of connected slabs but as one homogenous unit. I will welcome any suggestion or comments made with regard to this method.

(Sd.) MOHAMMED DEAN

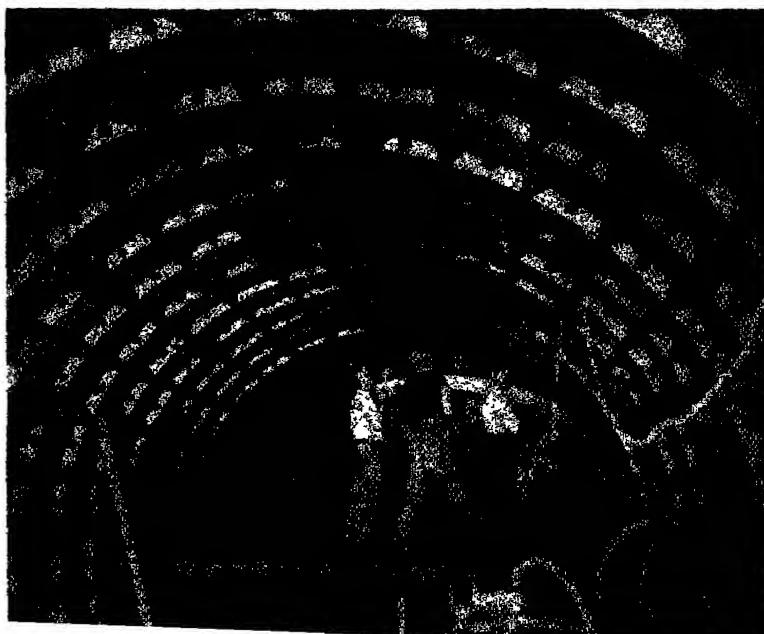
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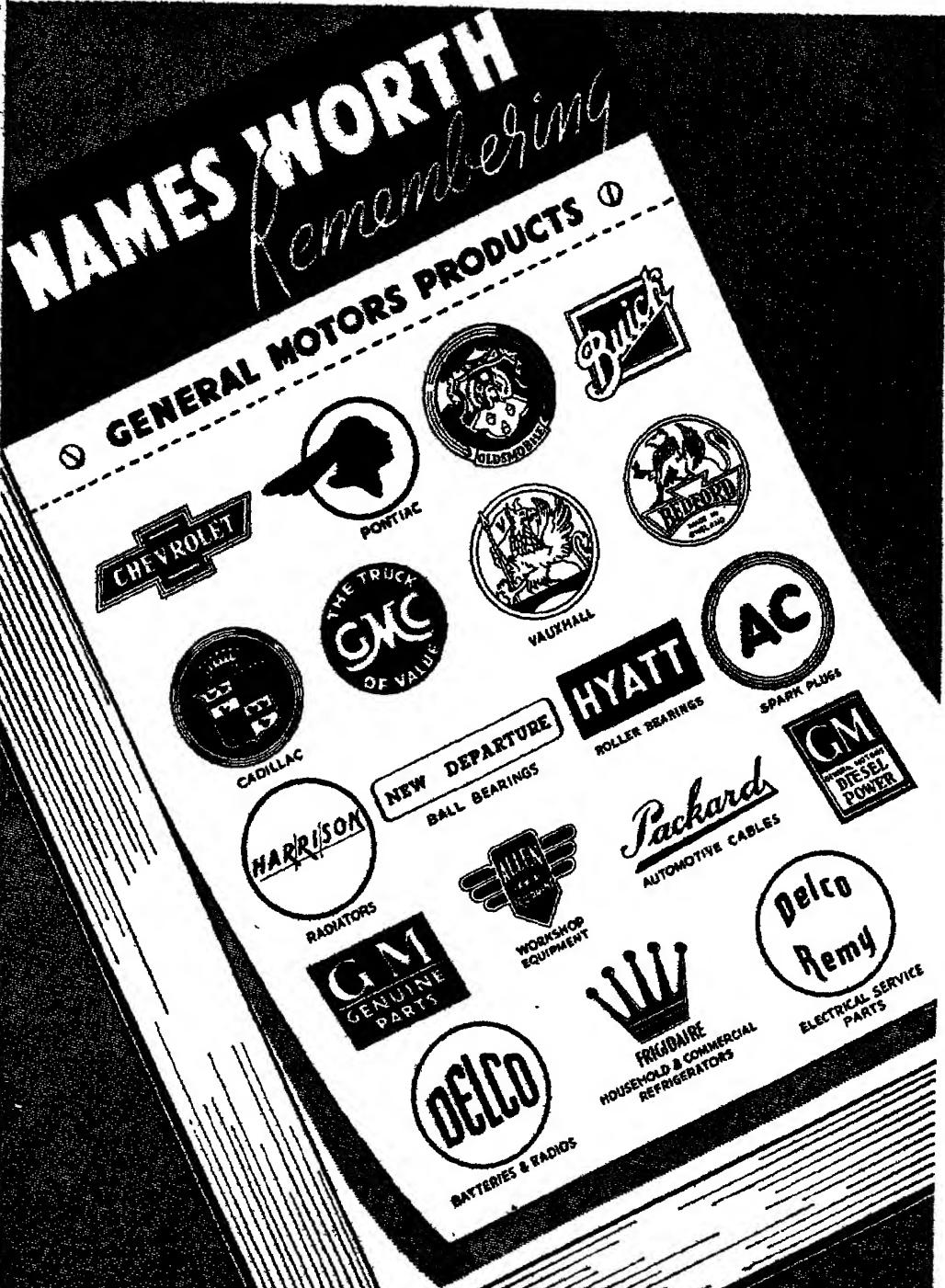


Rough sketch of longitudinal Section of road



WORK IN PROGRESS ON THE CONSTRUCTION OF A CONCRETE TUNNEL SHELTER AT LONDON TUBE STATION

May 18th, 1948



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1. A.R.P. number, May/June 1942 Re. 1-0
2. Roads number, February 1945 0-10

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 AMBALA CANTT
 ATRAULI ROAD
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 BAHMANI
 BARARA
 BARNALA
 BAGHPAT ROAD
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 BAHADURGARH
 BAHIJOL
 BABETTA
 BASIKIRATHPUR
 BAGAMABAD
 BHIWANI
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 BECDHLADA
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 CHOLA
 DADRI
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 DIBAI
 DEHRA DUN
 DELHI
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 DHAMPUR
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 DOIWALA
 ETMADPUR
 FARIDABAD
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 GANAUROH
 GANGOH
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 GOHANA
 GUNGGAON
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 JAKHAL
 JALESBAR ROAD
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 JULANA
 KALANWALI
 KANTH
 KANDHLA
 KAURARA
 KHATAULI
 KHEKRA
 KHURJA

CAWNPORE
 ACHALGANJ
 ACHHALDA
 AGBALI
 ANIMANPUR
 AHRABA ROAD
 AJGAIN
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VEHARI
VERKA
WAZILABAD
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KASHIPUR
KASIMPUR KHERI
KOSI KALAN
KOTDWALA
KURUKSHETRA
LEHRAGAGA
LAKHSAR
LOHARU
MANDI DHANAURA
MADLAUPA
MANSURPUR
MEERUT
MILAK
MORADABAD
MUNDLA NA
MURADNAGAR
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NAJIBBAD
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NAGINA
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PALWAL
PANIPAT
PATIALA
PILKUHWAA
RAIWALA
BAJA-KA-SAHAS-
PUR
RAJGHAT-NARORA
RAJPURA
RAMAN
RAMNAGAR
RAMPUR
RAMPUR MANHYA-
RAN
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SHAHHABAD MAR-
KANDA
SHAMLI
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SONEPAT
SIMDHAOLI
TAPA
TAPRI
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THANESAR
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BEWAR
BHADOHI
BHARTHANA
BHATPARRANI
BHATNI
BHITTAURA
BHITTI
BHONGAON
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BILGRAM
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BISWAN
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ALAL	KAITHAL
ALIGARH	KASHIPUR
AMROHA	KASIMPUR KHERI
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ATRAULI ROAD	KUROKSHETRA
BABRALA	LEHRAGAGA
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JANGIGANJ
JARWAL ROAD
JASWANTNAGAR
JAUNPUR
JEONATHPUR
JHANSI
JHUBI
KABRAI
KACHELA GHAT
KACHHWA ROAD
KADIPUR
KAIMGANJ
KALPI
KAMALGANJ
KAMALPUR
KANAUJ
KANCHHAUSI
KARAJI
KARENJI
KABWI
KASBANJ
KASHI
KATHODAM
KATHERUJIAN
KATKA
KAWAPUR
KEORUPUR
KERAKAT
KHADA
KHAGA
KHALILABAD
KHATEMA
KHETA SARAI
KHORASAN ROAD
KICHHA
KIDHADPUR
KOHDADUR
KONRE ROAD
KOPAGANJ
KUNCH
KUNRAGHAT
KUSMHI
LACHHMIPUR
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MAHOLA
MAHPUR
MAINPURI
MAKRANDPUR
MALIHABAD
MALIPUR
MALLAWAN
MANAURI
MANDAU ROAD
MANKAPUR
MANPUR NAGARIA
MARBEBA
MARLAU
MASKANWA
MAU AJIMA
MAU NATH
BHANJAN
MAURANIPUR
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MIRZAPUR
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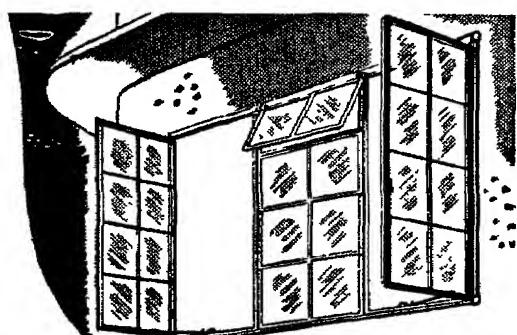
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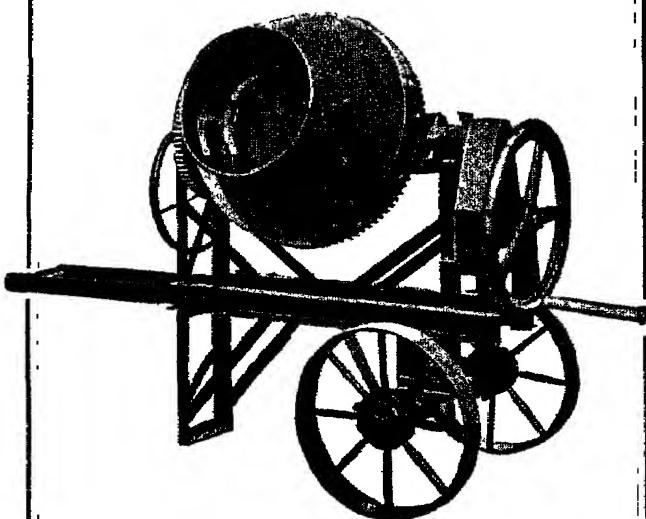
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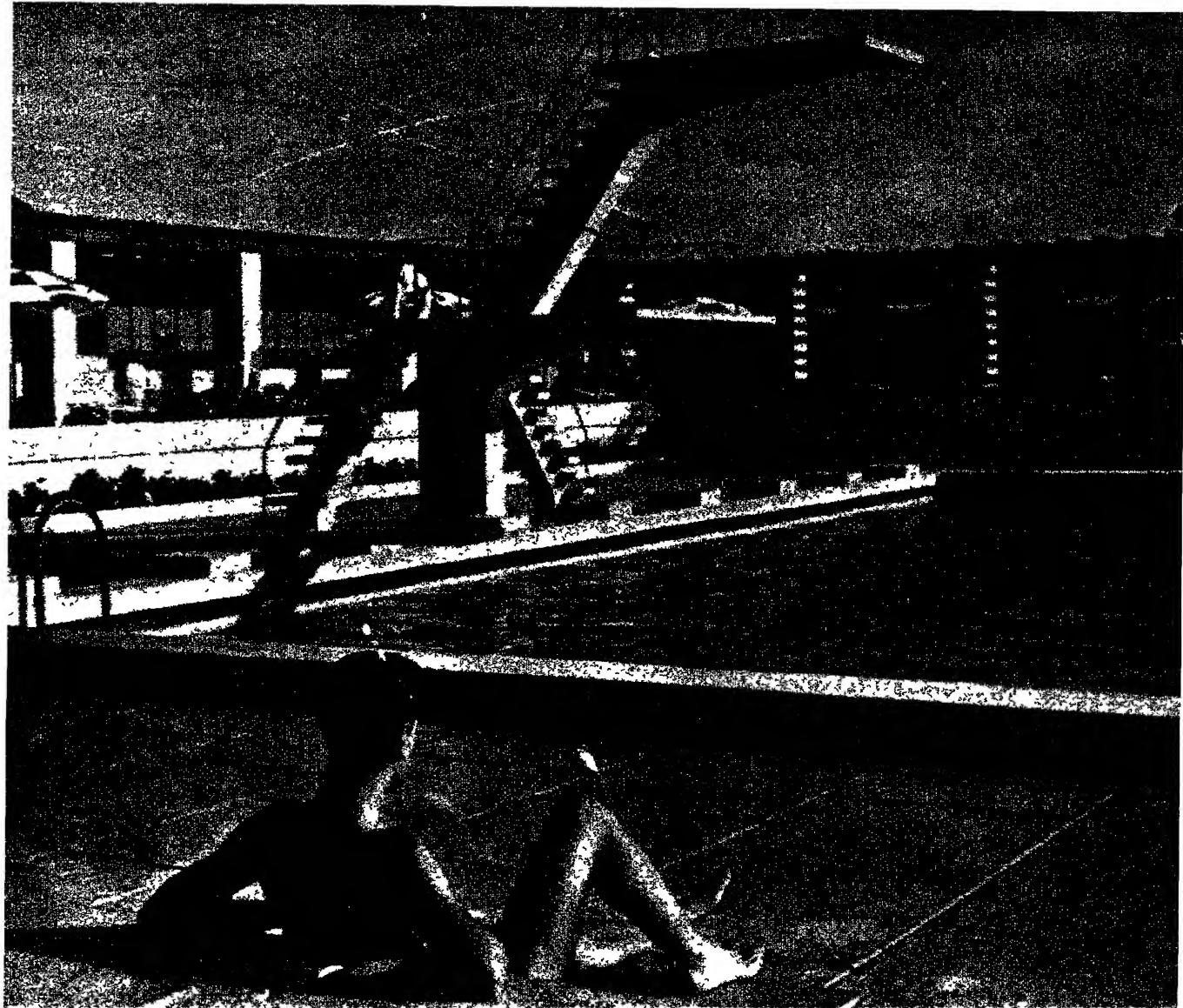


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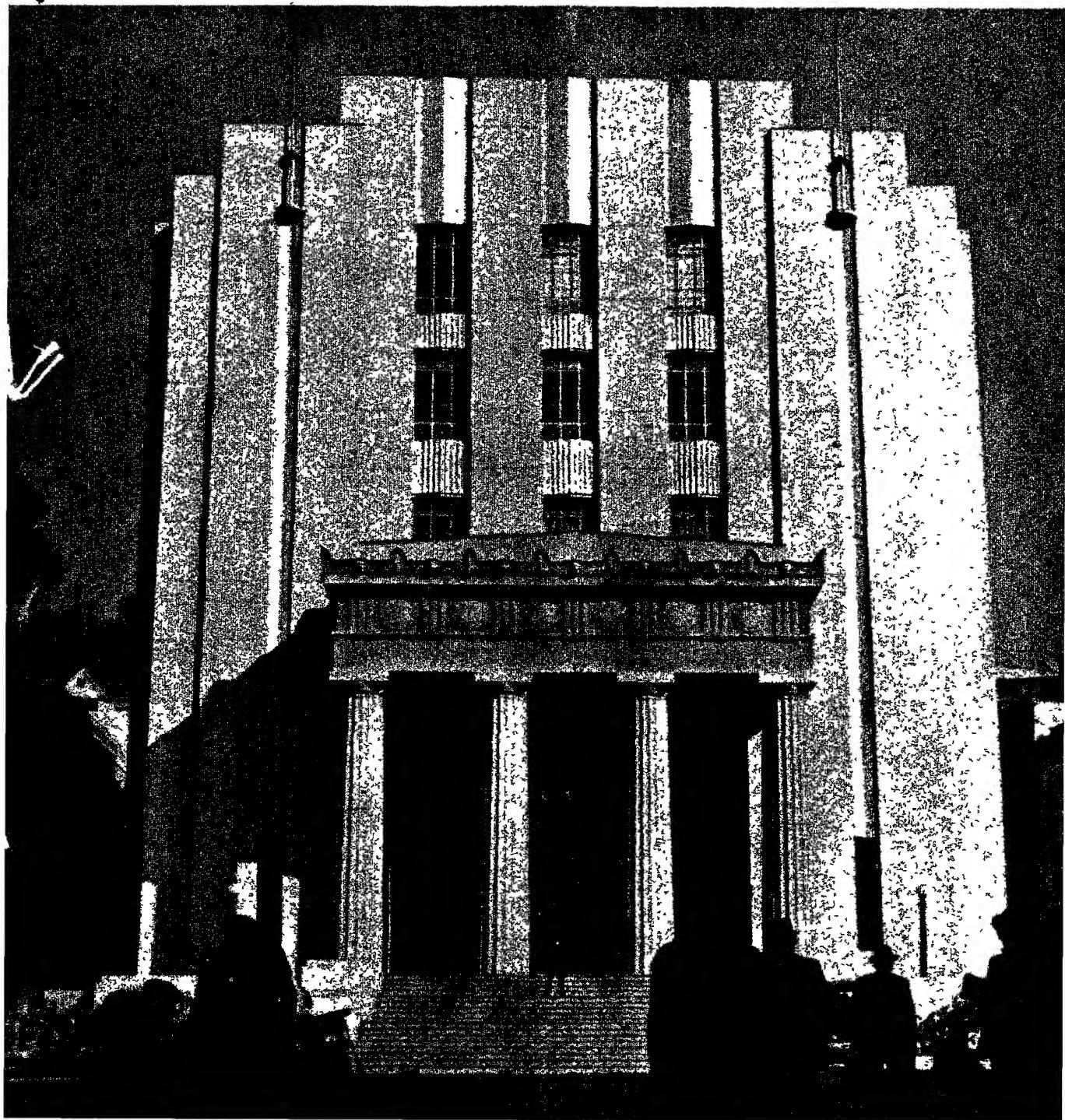
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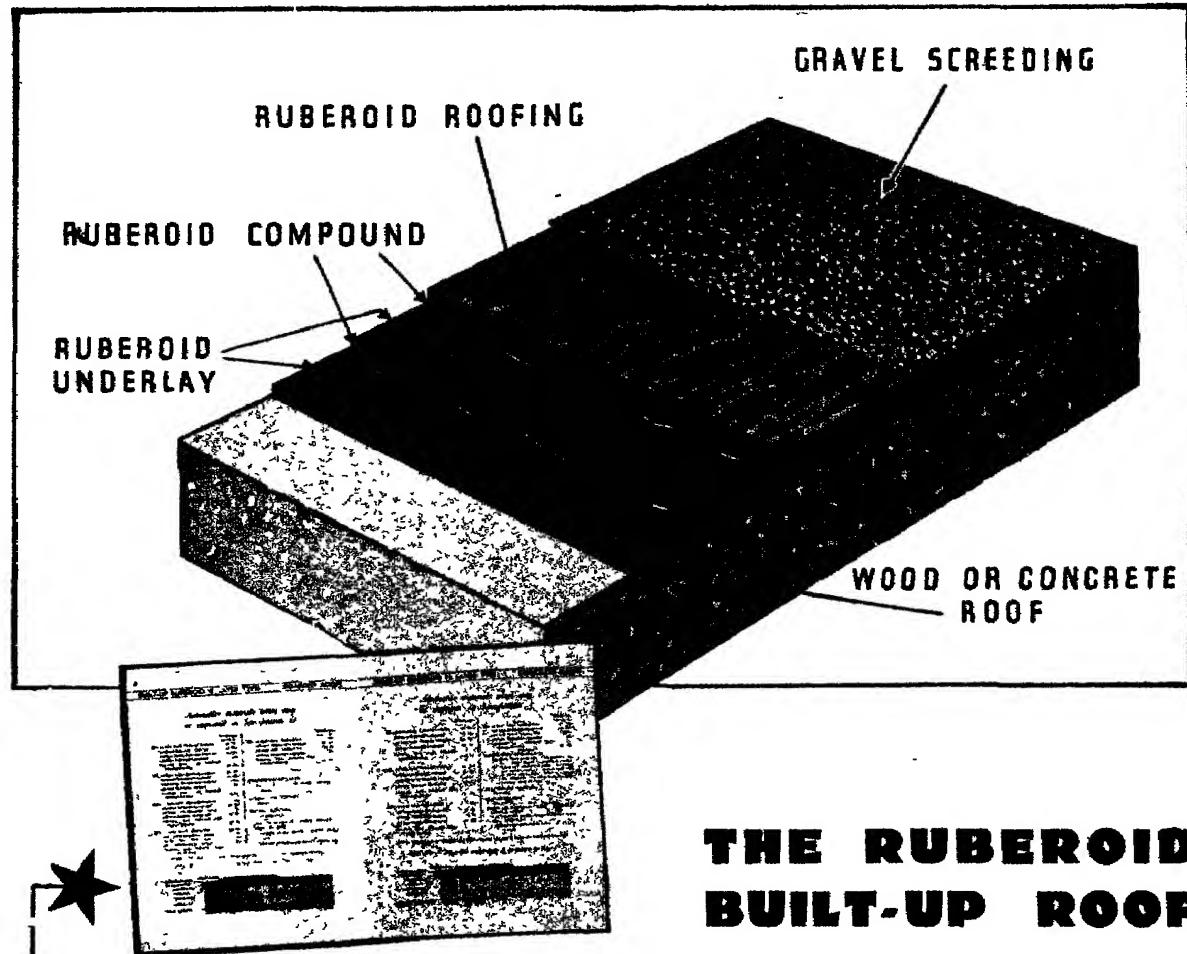
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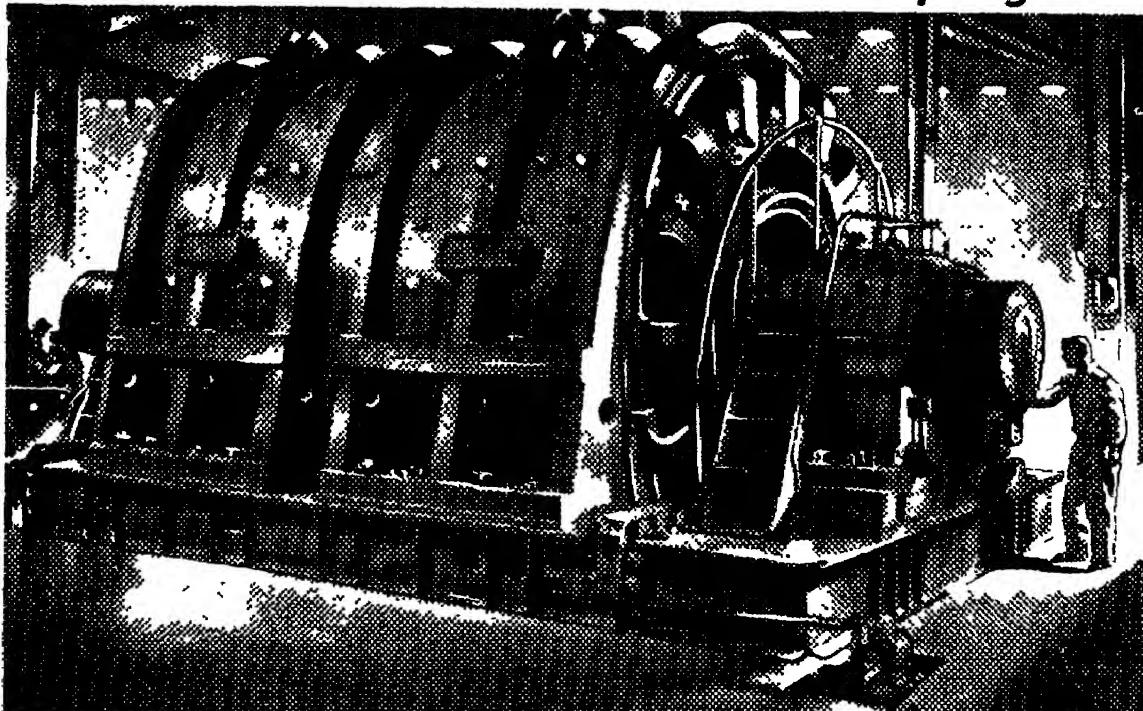
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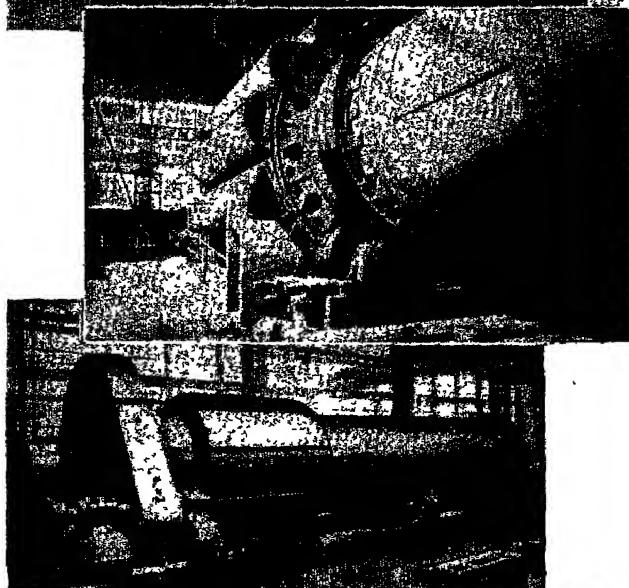
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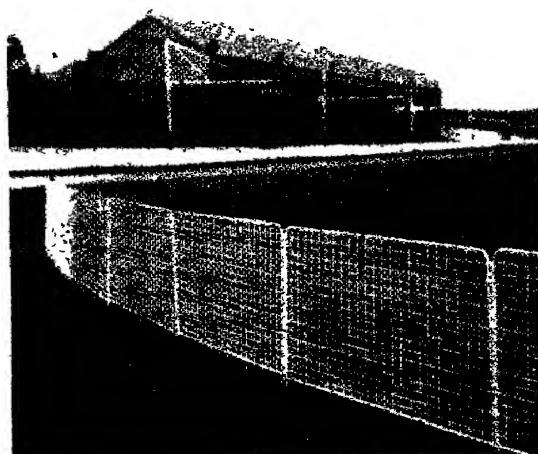
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American and British engineers and construction equipment work together in removing battle debris from Naples, foreshadowing a post-invasion task that will be duplicated in many other European cities during 1945.

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EDITORIAL NEWS & NOTES

TRANSPORT AFTER THE WAR



We published last month the editorial comments made by "Highways, Bridges and Aerodromes" in their issue of the 21st March 1945

As the matter of post-war transport is vital to India we make no apologies for printing further comments which appeared in another issue of the same paper

There is no doubt that the step-motherly treatment meted out to road, is in a measure due to the lack of knowledge on the part of the general public of the true significance of road transport. Railway interests appear to be all-powerful in both countries and, while no one can belittle the very fine work the Railways have done in this war, we must continue to plead the cause of roads which, if allowed reasonably fair play, could do as much or even more than the railways in what we hope may be the peaceful days ahead

TRANSPORT after the war is the subject of much debate just now, but the majority of proposals by persons and organisations contain railway apologia. This is not entirely to be wondered at, considering the vast ramifications of the railways. It is quite wrong to regard the railways as nothing more than transport agents. Transport is but one of a vast number of interests which, as at one time transport monopolists, they were able to develop and hold. They are the largest hoteliers, licensed victuallers, and general caterers in the country. They are owners of docks, warehouses, and they practically control the distribution of coal. They are the largest purchasers of steel, building materials, and commodities of every description. Their 'Facts About the Railways' publication falls far short of doing justice to the vastness of their undertakings. As we have stated, the railways are not purely transport agents, but rather a vast trading organisation, and the largest purchasers of goods and materials of all kinds in the country, in addition to being manufacturers of all manner of goods on a huge scale. The withdrawal of railway orders would bankrupt many a firm, inconvenience thousands of others, and seriously injure as many more. In short, they have a vice-like grip on British industry which they tighten or relax as it suits their interest. No wonder their political power is so immense, and, naturally enough, it is to their interest to obstruct, with the utmost vigour, the construction of a system of roads which would meet the requirements of modern road traffic. They have achieved this dominating position in British industry, owing to the fact that until recent years they have held the lines of communication, which are just as important in peacetime as in war. Whenever it is proposed to erect a factory, those responsible give priority consideration to transport facilities when selecting the site. There are, of course, many other factors governing the final decision, but, without transport, a factory is useless, and so, until quite recently, manufacturing industry has collected about railway centres, with the disastrous results which the Town and Country Planning Ministry and town planners generally are seeking to remedy.

The psychological effect of this railway dominance on the public is remarkable. The public resents most things when it is compelled to take that which it is offered rather than that which it would prefer, but in the case of the railways the man

in the street appears to take a pride in the railway undertaking. Railway administration is aware of this, and, therefore, publishes its pamphlet 'Facts About the Railways'. The railway traveller complains about the discomforts he endures, but is more prone to excuse the railways than to blame them. Alternative means of travel are available, but are not allowed to develop, and only now are road transport organisations beginning to object, but as yet no organised propaganda has been started, and so objections have little weight behind them.

The resentment of railway dictation has possibly grown more as the result of the curtailment of private motoring than the multitudinous restrictions on industrial motoring have had. It touches the quick. Harking back to the Railway (Road Transport) Act 1938, it is pertinent to ask how many manufacturers of industrial motors went out of business soon after the railways were given powers to provide road transport services and the Road Transport Commissioners (1939 Road Traffic Act) were appointed to close the doors to new entrants to the road transport carrying services and to all intents and purposes, to refuse additional 'A' licences to all except the railways, which have had but gesture refusals? There is no need to enlarge on the dire results of so pro-railway legislation.

We note with satisfaction that motorising organisations have now started a campaign, which we trust will grow in intensity, against motor taxation, which campaign, we claim, was initiated in the pages of this journal. Paradoxical as it may seem motor taxation, particularly the petrol duty, is impedimental to road improvements, because for one thing the worse the roads the more devious the routes, and the more frequent the road blocks the greater the petrol consumption, and so the more lucrative the revenue derived from it. It ignores the fact that the wastage of fuel is an additional tax on production. There should be no tax on transport. The petrol tax is particularly vicious, for the reason that it hits industry more than anything else. When the fuel duty was first introduced our contemporary 'Motor Transport' ('Motor Traction' in those days) raised objection to the taxation of fuel for industrial motoring and succeeded in obtaining a concession which was, however, later cancelled.

We come now to the question. What has motor transport to offer as compared with rail transport? Every motor user knows its advantage as it affects him

personally, but there is no general knowledge regarding its advantages. Door-to-door delivery is the most salient feature, whether for persons or goods, but its advantages are not fully appreciated. It would be futile for us to attempt to estimate the number of the millions upon millions of goods transported daily, and in the transport of which motor transport eliminates at least two handlings. What the value of this reduction of handling is is also of a magnitude it is impossible to estimate. The time saved in transport is another of those things which cannot be estimated in its monetary value, but industrialists tell us that in one day they can transport a consignment which would take five days or more by rail. Another point the consumer is fed according to his capacity to consume—that is he is no longer compelled to provide huge storage for goods, he may not require for days, weeks, or months, so that he may get the lower rates the railways offer for large consignments. The firm owning its own transport, or making suitable arrangements with a road operating firm, can despatch his goods at any time to suit his convenience, and he has control over the goods from the time they leave his premises until they reach their destination. The breakages of fragile goods by road are more than 75 per cent less than by rail. The foregoing are but just a few of the advantages of road transport as compared with rail, but they might, with advantage, be enumerated in more detail. They are advantages which are available even to-day, in spite of adverse legislation which amongst other things introduced speed limits necessitated by road defects, such as their tortuous windings, narrowness, bad lighting, and other things. How much more then, could all the advantages road transport offers be improved and converted into a mighty national asset if the roads were scientifically designed and constructed? This is a problem which is of particular interest and importance at the present time, in view of the fact that even to achieve the prosperity which was normal previous to the war, the country must increase its exports by, at the very least, 10 per cent beyond the 1939 figure. No one but a fool can under-estimate the value of transport in the essential trade recovery which is so vital and nothing can relieve the burden of transport so much as the provision of an adequate road system.

The country has bowed and scraped far too much to this railway Goliath which reached its peak of utility years ago, and has degenerated from the blessing it was at one time to the incubus it has now become. Done like to dispense with the services of an old and faithful servant, but there comes a time when owing to infirmity that servant should be pensioned off, and, we maintain, that if the Government feels that responsibility towards the railways, it should take that attitude towards them leaving them to provide those services of which they are still capable and transfer other services to their more versatile and capable successor."

CEMENT AND WAR

(Contributed)

DEALING first with the European theatre of war, cement has proved invaluable in many directions

From a defensive standpoint, it has been used for the making of concrete—both plain and reinforced—for A R P shelters and innumerable other things. Results have proved that reinforced concrete properly made is the best material for resisting destruction by bombs. It is fireproof, and extremely resistant to shock of every kind. Shelters made of this material are readily cleaned, and kept free from insects and vermin. One of the great needs in fighting bombs is water, and tanks lined with concrete have proved invaluable for this work. Splinter-proof walling has used concrete of every variety, and hollow blocks have played an important part in this form of construction. Then, again, there have been indoor shelters, sentry-boxes, first-aid posts made of concrete, both in the precast variety, and laid in situ. Concrete pipes have also been used for shelter purposes. Concrete load blocks and tank traps were used in anti-invasion defences. Concrete spikes known as dragon's teeth were used largely by the Germans in making their famous Siegfried Line and the French used thousands of tons in the Maginot Line. Another use of concrete is in slabs as bursting courses for dug-outs to detonate shells or bombs, thereby preventing them from reaching the occupants of the shelter below ground. For the storage of explosives and other essential materials concrete has proved invaluable.

On the Offensive.

So much for defence and protection. Let us now turn to the other war uses

for an army on the offensive. Perhaps the concrete runways and aerodromes are of greatest importance. Thousands of acres of concrete have been laid for runways for the main landing and taking-off strips, many of which are well over a mile in length, and about 150 feet broad. Then there are taxi strips, on which planes move from their shelters to the runways. Concrete also plays an important part in aerodrome hangars, observation towers, buildings of every sort in connection with aerodrome work.

Transport.

Next we come to transport. The life-blood of modern warfare is transportation. England and America, being separated by sea from the theatre of war, have to employ ships to carry men and materials to the scene of operation, and astounding things were done in connection with what is known as "D" Day. Vast concrete floating docks were precast and towed to the landing sites. Concrete barges of every kind were used both for transportation and for bridging. Floating breakwaters were also made of this material. Ordinary road surfaces get cut up very quickly by modern war transport and concrete has proved of immense value both to the enemy and to ourselves for the building of arterial and strategic roads. The Reich *autobahnen* were renowned throughout the world as perhaps the greatest system of concrete roads of all time, and we now know that these were very largely laid out by the Nazi regime for purposes of rapid transportation of troops and materials from one front to another.

In the meantime, America's concrete roads, of which there are well over a

hundred thousand miles, have been of the greatest value in allowing transport to move freely and rapidly across the Continent of America. Permanent docks, both dry and wet, have facilitated the embarkation and disembarkation of goods of every sort. Piers and jetties of this material jut out into the sea in a thousand places, and, in every case, concrete proves its value in its resistance to salt-water and the ordinary ravages of time.

In actual warfare it is such things as gun-emplacements, pill-boxes, tank traps, machine-gun posts, lookout posts, all made of concrete, which help win the war. Many articles which would have been made of steel have been made of concrete and, in many cases, even the reinforcing steel has been saved by designing the concrete in mass or in arch construction.

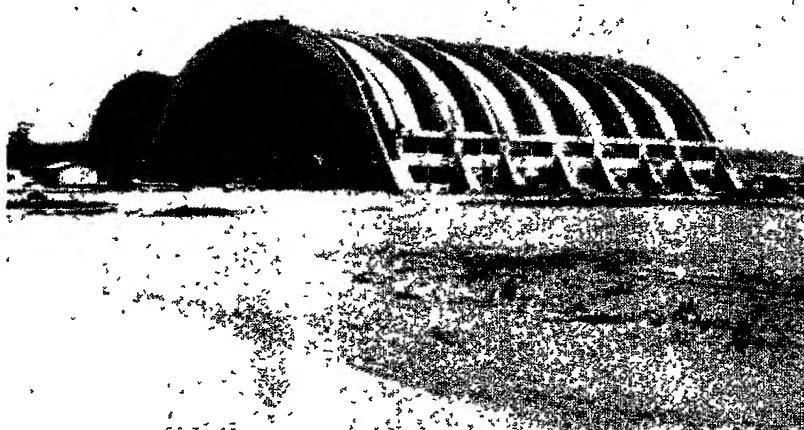
Asbestos-Cement Products.

Cement has also played an immense part in association with asbestos to form asbestos-cement products in infinite varieties. It is used in all kinds of roofing, both flat and curved, and it is even adapted to the Nissen type of hut for military and other housing. It is light, of low conductivity and comparatively cheap. To replace steel tubes, asbestos-cement pipes have been used with special fittings to form struttied trusses. Light-weight tanks and cisterns, louvres, ventilators, and portable silos, are amongst its many uses, both in war and in peace. In munition factories, enormous quantities of cement have been used for the humble, but useful, concrete flooring, which is now practically universal, owing to the ease with which it can be kept clean.

Indian Cement.

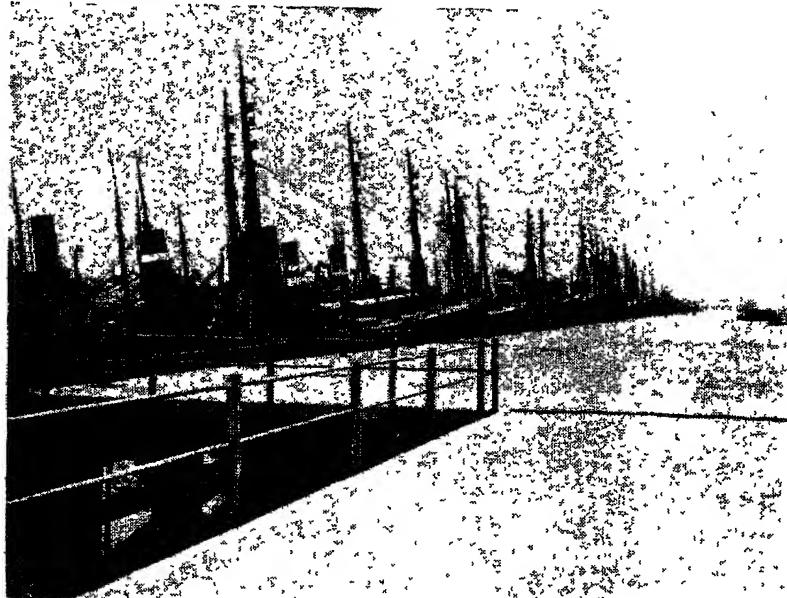
Practically everything that has been mentioned in connection with the war in Europe, applies, as far as cement is concerned, to the Eastern war, Indian cement being no whit behind its European prototype. Vast quantities are being used for aerodromes, runways and strategic roads, godowns, sheds of every kind, aerodrome hangars, storage tanks, etc. In India, enormous lengths of Hume pipe have been used for war purposes. The Hume pipe process consists of spinning concrete inside a mould, so that the centrifugal action makes the resulting mixture extremely dense, driving off all but the necessary amount of water to make good concrete. These pipes are used not only for carrying water, but even sewage, where this is not too concentrated.

Tiles in every shape and size have also been laid for floors, dadoes, and walls of rooms, clinics, hospitals, etc. Owing to the enormous requirements of cement in war-time, the civil market has necessarily had to be starved, but it is hoped that, with the return of normal times, this cement vacuum will be filled, and the new uses shown to us by war will be of vital importance in the building up of peaceful reconstruction. The extensive damage, which has been done by shells, bombs, and tanks, will have to be repaired some-



Concrete Construction in War-time.—Reinforced Concrete Hangar, 294 ft. span and 81 ft. high, under construction at San Diego, U.S.A.

June 15th, 1945

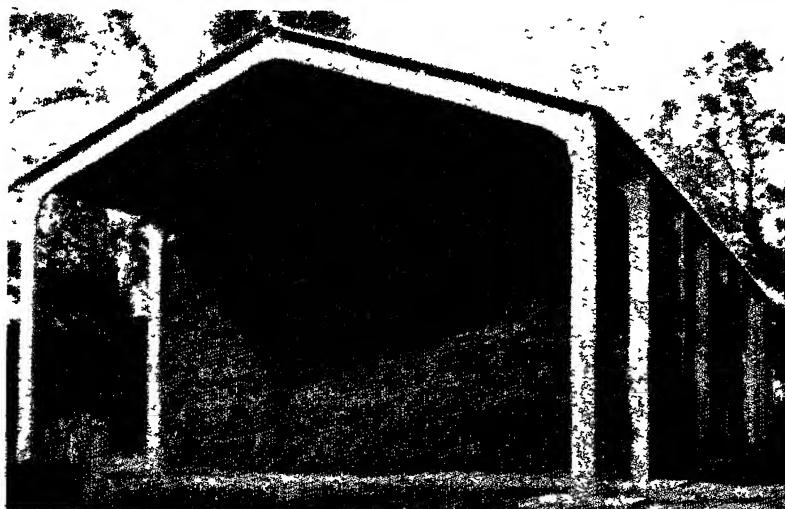


Reinforced Concrete is the ideal construction for wharves

how, and there is not the slightest doubt but that cement and asbestos-cement will both play a very important part

Post-war Prospects.

When peace again returns cement will have great national importance, being,



The clear-span concrete construction was developed for use in the erection of this Dutch barn in South Wales.

as it is, one of the few commodities that can enter into practically every scheme of the national programme of rehabilitation and development, assisting to make better communications, more sanitary and healthful village units, and better housing for the agriculturists.

One of the things the war has taught us is to use cement in stabilising or consolidating soil, and, here, there is a great future in connection with Indian rural highways, but, in order to make soil stabilisation a hundred per cent. useful, we must try and substitute pneumatic tyres for iron wheels on the millions of bullock carts which, to-day, by ripping up our roads, are wasting crores of rupees annually.

The cement industry of India is fully alive to the immense demands that will be made on it when a world at peace resumes its normal avocations.

Few people realise that, including transport of coal and cement, one ton of cement needs the best part of half a ton of coal. First, coal has to be used in the locomotive which draws the coal from the mine to the factory, often several thousands of miles, then, coal dust has to be used for calcining the mixture of limestone and clay to clinker, after which coal is used to make the steam to drive the alternators which give the power to the works, then more coal has to be used to take the cement to wherever it is needed. Every ton of cement needs 20 jute bag containers, and more coal is needed to carry the jute bags. So we are inclined to call coal the bottleneck, but the real bottleneck lies in the difficulty of getting labour to win the coal cheaply and this bottleneck must be opened out before cheap cement can possibly be made available. When the cement is delivered to the site where it is to be used, more labour is required to mix it with stone, sand and water. Expert supervisors must be employed to see that the proportions are correct and that the ingredients are clean. Cement will not stick to dirt.

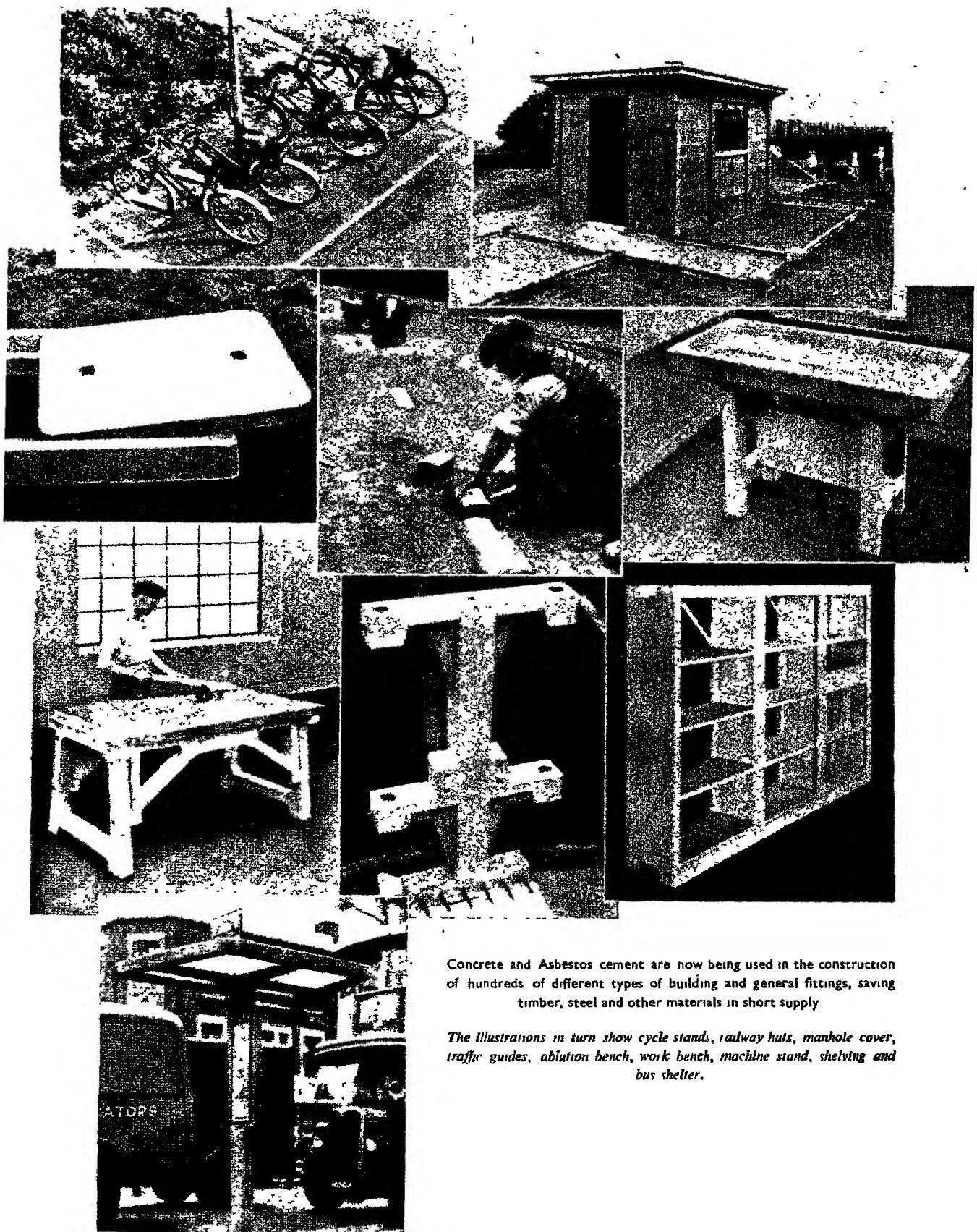
Carpenters are required to build the moulds or forms into which the concrete is poured and, finally, large gangs of women coolies are employed in curing the concrete to prevent the hot sun of India drying it out too quickly.

Thus we see that cement helps industry in almost every direction, and thankful we ought to be that India can make not only all the cement she requires but the standard is equal to the highest in the world.—(With acknowledgments to "Commerce", Bombay.)

CONTRIBUTIONS

Articles and photographs suitable for publication in *The Indian Concrete Journal* are always welcome, and those that are accepted, will be paid for at our standard rates.

MISCELLANEOUS CONCRETE PRODUCTS



Concrete and Asbestos cement are now being used in the construction of hundreds of different types of building and general fittings, saving timber, steel and other materials in short supply

The illustrations in turn show cycle stands, railway huts, manhole cover, traffic guides, ablution bench, work bench, machine stand, shelving and bus shelter.

PHYSICAL PROPERTIES OF CEMENTS

PART I.

Mechanical Analyses of Cements

By AMAR NATH PURI, BALWANT RAI and D. D. VOHRA, Punjab University Institute of Chemistry, Lahore.

THE effect of the nature of granular structure on the strength of cement has not been studied extensively. Until recently it was generally accepted without any experimental proof that extremely fine grinding would greatly improve the strength of the cement. It has recently been shown* that the strength of cements is also reduced when the grinding is extremely fine. There is actually an optimum state when the cement strength is the maximum. This is supposed to be due to the fact that hardening of cements is brought about by the shrinkage of a gel-mass resulting from "Internal Absorption". Two conditions, therefore, are operating, namely the formation of the gel assisted by fine grinding and the shrinkage of the gel-mass brought about by the coarse grains of cement that are embedded in the gel. These two opposing conditions set a limit to the fineness of grinding leading to increase in strength. It is clear, therefore, that an accurate knowledge of the mechanical analysis of cements should prove of great importance for the development of high-strength cements. No satisfactory method has been discovered so far for the purpose. Sieves do not carry us much beyond 0.02 mm diameter even with the finest mesh. Air elutriators have never proved suitable for precision work though for approximate analysis they are sometimes useful. Other methods would be suitable provided we use alcohol or kerosene oil as the sedimenting liquid. A sedimentation apparatus using alcohol as the sedimenting liquid has been described by Kuhl and Ozernin (loc cit).

The apparatus consists of a long tube filled with alcohol, in the uppermost layer of which the sample of cement is thoroughly dispersed and allowed to fall freely. In order to collect and measure the individual fractions, a discharge arrangement is used on the principle of a slowly flowing stream of alcohol issuing in drops from the tube. This stream carries out of the apparatus particles which have reached the bottom of the tube and are collected in a series of filters disposed on a rotating stand beneath the apparatus. A novel feature of the sedimenting cylinder is the temperature gradient which is established by heating electrically different portions of the cylinder. This is supposed to compensate for the density gradient established by the cement suspension which otherwise sinks as a whole. There appear to be two serious defects about this instrument, namely the slowly moving stream of alcohol and the temperature gradient

which will set convection currents. The authors have not given much convincing data to show the working of this apparatus. As already pointed out, the choice of ordinary sedimentation methods familiar to soil workers is restricted by the fact that water cannot be used as a sedimenting liquid. We can, however, follow two lines of attack (a) the use of liquids other than water, (b) the pre-treatment of cement which will render it inactive towards water. The object of this paper is to describe the development of methods falling under these categories.

Four samples of cements were used for the purposes of this investigation.

Use of Sedimenting Liquids other than Water.

The following liquids were used:

Kero-ene oil, Benzene and Alcohol. Particles of diameter 0.02 to 0.6 mm were determined by the pipette method. Coarser fractions were determined in the Puri Siltometer which consists of a long tube filled with water or the appropriate liquid, the sample to be analysed is dropped in this tube and as particles of different sizes fall with different velocities they are collected in different boxes which move in position at predetermined intervals of time. The various fractions are thus separated according to their settling velocities and the appropriate diameters are assigned in accordance with the well known Stokes Law

$$V = \frac{2}{9} g \frac{\delta - \delta'}{\eta} r^2$$

where V = Rate of fall in centimeters per second

δ = Density of falling particle

δ' = Density of liquid

η = Viscosity of liquid

r = Radius of the particle and

g = gravitational constant

In order to apply Stokes' law to the mechanical analysis of cements in the various liquids, density of cement samples and densities of various liquids as well as their viscosities had to be determined and are given below —

Density of Cements

Sample No 1 = 2.012	
, No 2 = 2.024	
, No 3 = 2.003	
, No 4 = 2.031	
—	
Mean 2.012	

The mean value was taken for all calculations of the rate of fall of particles of various sizes

TABLE I
DENSITIES AND VISCOSITIES OF DIFFERENT LIQUIDS

Liquid	Density	Viscosity
Kero-ene oil	0.873 (35°C)	0.0188 (35°C)
Alcohol	0.7860 (35°C)	0.0171 (35°C)
Benzene	0.882 (25°C)	0.0166 (25°C)

The determination of the above constants were made at the prevailing temperatures and the mechanical analyses were done at the same temperature. Variations of temperature of the order of $\pm 5^\circ\text{C}$ will not affect the results appreciably, though for very accurate work temperature corrections must be applied.

The time of settling of cement particles of various sizes in different liquids through a distance of 10 cm as calculated from Stokes' law are given below —

TABLE II
TIME OF SETTLING OF PARTICLES THROUGH 10 CMS. DISTANCE

Particle diameter (mm)	Time of settling through 10 cms. depth			
	Water and (35°C) Min. Sec.	Alcohol (18°C) Min. Sec.	Benzene (25°C) Min. Sec.	Water (25°C) Min. Sec.
0.6	0.37	0.31	0.37	0.218
0.1	0.81	0.69	0.31	0.46
0.2	2.25	1.36	2.15	1.23
0.1	22.42	25.21	9.6	11.53
0.08	33.54	26.45	14.4	21.14
0.06	40.61	50.7	25.2	41.6
0.04	133.55	125.0	55.1	92.0
0.03	512.20	400.0	25.0	172.30

Similarly the sizes of particles falling in different boxes of the Puri Siltometer after various predetermined intervals of time were calculated and are given below

TABLE III
TIME OF FALL OF VARIOUS PARTICLES IN DIFFERENT LIQUIDS IN PURI SILTOMETER USING 200 CMS. TUBE LENGTH

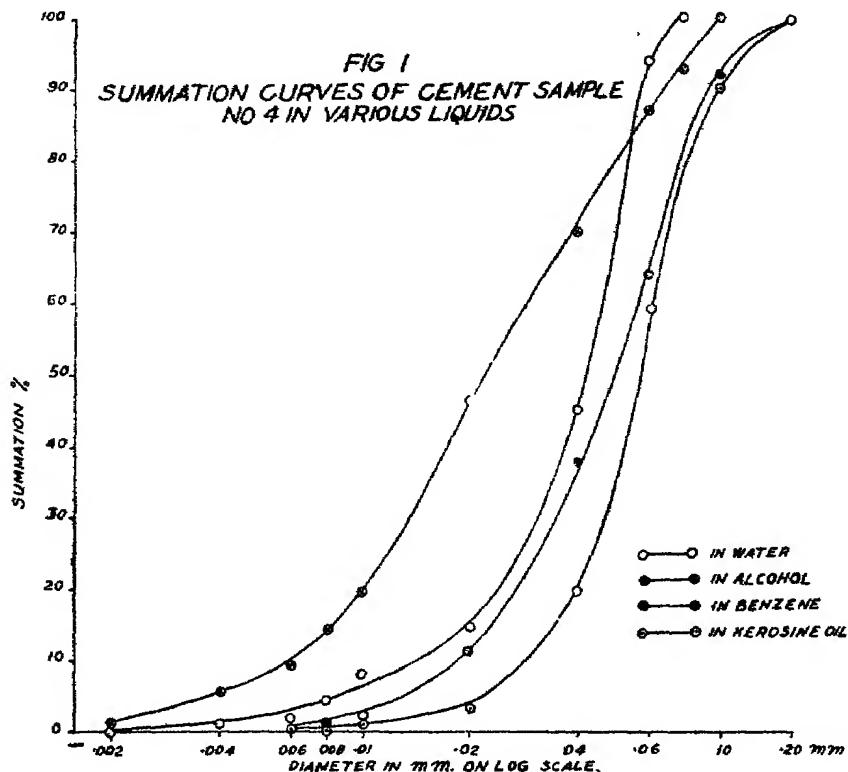
Diameter of Particle (mm)	TIME OF SETTLING IN —			
	Water (second)	Alcohol (second)	Benzene (second)	
0.17 mm	21.6	27.2	41.2	22.4
0.15	25.0	37.4	52.5	25.8
0.13	28.2	35.5	54.0	27.5
0.10	37.5	52.7	54.0	39.5
0.09	37.8	53.2	55.0	37.6
0.08	28.2	45.0	42.6	27.7
0.07	41.4	52.1	45.6	35.7
0.06	44.4	56.2	49.3	27.8
0.05	45.1	60.6	52.4	26.8
0.04	51.4	61.7	55.3	31.9
0.03	54.8	60.1	56.6	34.7
0.025	63.3	29.7	70.4	37.1
0.02	71.4	50.0	52.1	41.3
0.019	76.7	100	59.6	39.3
0.015	88.0	121.0	57.8	53.0
0.015	112.9	143.2	125.2	70.0
0.013	137.8	173.0	151.3	85.4
0.012	162.7	205.0	151.2	101.0
0.008	412.1	303.4	347.3	103.5
0.007	615.5	582.5	421.7	240.2

* Cement Chemistry in Theory and Practice by Han. Kuhl, translated by J. W. Cristelow

The results of mechanical analyses of all the four cements in the four liquids are given in Table 3, and those obtained in case of one of the samples are plotted in Fig. 1.

These results show that the mechanical analysis in kerosene oil represents the coarsest aggregation, benzene comes next. Alcohol give the greatest disintegration and may be that it represents the true state of aggregation as it exists in the powdered cement. The results are not reliable in the case of water and are given

by way of comparison. As a matter of fact cement particles soon form hydrates with water, swell up and coalesce with other particles and their rate of settling increases. It is seen that .06 mm particles have nearly the same summation percentages in water as well as alcohol, but as far as finer particles are concerned, the deviations become considerable. This is because with the increase in time of contact of cement with water, there is a greater coalescence of finer particles which behave as coarser fractions.



The primary particles in all disperse systems have a tendency to form aggregates or compound particles. Such aggregates or compound particles are quite common in the case of soils and their breakdown to ultimate units is the main object of all preliminary treatments for their mechanical analysis. This object in the case of soils can be achieved either by chemical or mechanical means. Of the purely mechanical methods shaking with a quantity of coarse sand has been advocated in a recent paper by Puri and co-workers*. This method has certain advantages over others in the case of soils and it was felt that this preliminary treatment would result in the breakdown of the aggregates in the case of cements as well. Cement No 4 was selected for this purpose 10 gms of cement were shaken for 24 hours with 50 gms of coarse sand (1.5 mm diameter) in various liquids including water. The results are given in Table IV, and plotted in Fig. 2.

A comparison between Tables III and IV will show that dispersion with sand has resulted in the production of a larger percentage of finer fractions in every case. It has been shown in the case of soils that dispersion with the help of sand does not result in the production of any particles that were not already there. In other words it does not result in the breakdown of the primary units and only helps in the dispersion of the secondary aggregates. It would seem therefore that some sort of mechanical aid to dispersion would be required when analysing cements in the various liquids. Another interesting point that emerges from these results is that cement can be mechanically analysed in water provided it is dispersed by shaking with 5 times the weight of coarse sand for 24 hours. These results will be referred to again in the next section.

* Puri, A. N. Prabh Dsai and Balwant Rai 1944, "Mechanical Methods of Dispersion" Ind. Jour. Agr. Sci., 14, 64.

TABLE III
MECHANICAL ANALYSIS OF DIFFERENT CEMENT SAMPLES IN DIFFERENT LIQUIDS
Summation in percentages of particles of various sizes in different liquids

Liquid.	.002 mm	.004 mm	.006 mm	.008 mm	.01 mm	.02 mm	.04 mm	.06 mm	.08 mm	.12 mm	.15 mm	.18 mm	.20 mm
Cement No 1	Water	Nil	Nil	2.1	4.0	6.5	15.4	35.5	88.5	100.0	98.4	99.6	100.0
	K Oil	Nil	Nil	0.25	0.75	1.6	4.8	19.0	47.5	95.9	92.0	98.5	99.4
	Benzene	Nil	Nil	0.5	1.5	3.4	16.6	41.5	59.3	97.8	100.0	100.0	100.0
	Alcohol	1.0	2.0	11.2	13.5	21.0	46.1	73.5	86.0	93.4	100.0	100.0	100.0
Cement No 2	Water	Nil	Nil	1.9	4.5	5.4	15.4	35.0	89.5	100.0	96.5	98.7	100.0
	K Oil	Nil	Nil	0.5	1.5	3.8	12.1	47.4	93.9	96.6	98.1	99.5	100.0
	Benzene	Nil	Nil	0.5	1.0	4.5	12.2	40.5	63.0	93.5	99.2	100.0	100.0
	Alcohol	Nil	3.5	7.5	10.4	20.0	45.5	71.0	85.2	93.9	100.0	100.0	100.0
Cement No 3	Water	Nil	1.0	2.0	6.0	7.5	16.8	34.5	86.5	100.0	97.2	98.5	100.0
	K Oil	Nil	Nil	0.2	1.25	1.66	4.0	24.2	65.2	95.4	95.1	98.3	99.7
	Benzene	Nil	Nil	1.0	1.5	5.0	15.4	42.0	65.5	88.0	99.8	100.0	100.0
	Alcohol	2.5	4.0	12.1	14.0	23.4	44.0	73.2	88.5	96.0	100.0	100.0	100.0
Cement No 4	Water	Nil	1.5	2.1	4.2	8.5	14.9	45.0	94.0	100.0
	K Oil	Nil	Nil	0.25	1.25	3.5	20.0	59.5	95.6	97.6	99.2	100.0	100.0
	Benzene	Nil	Nil	1.0	2.5	11.5	38.2	63.9	92.5	97.5	98.9	100.0	100.0
	Alcohol	1.5	6.0	9.4	14.5	20.0	46.5	70.4	87.0	92.9	96.7	100.0	100.0

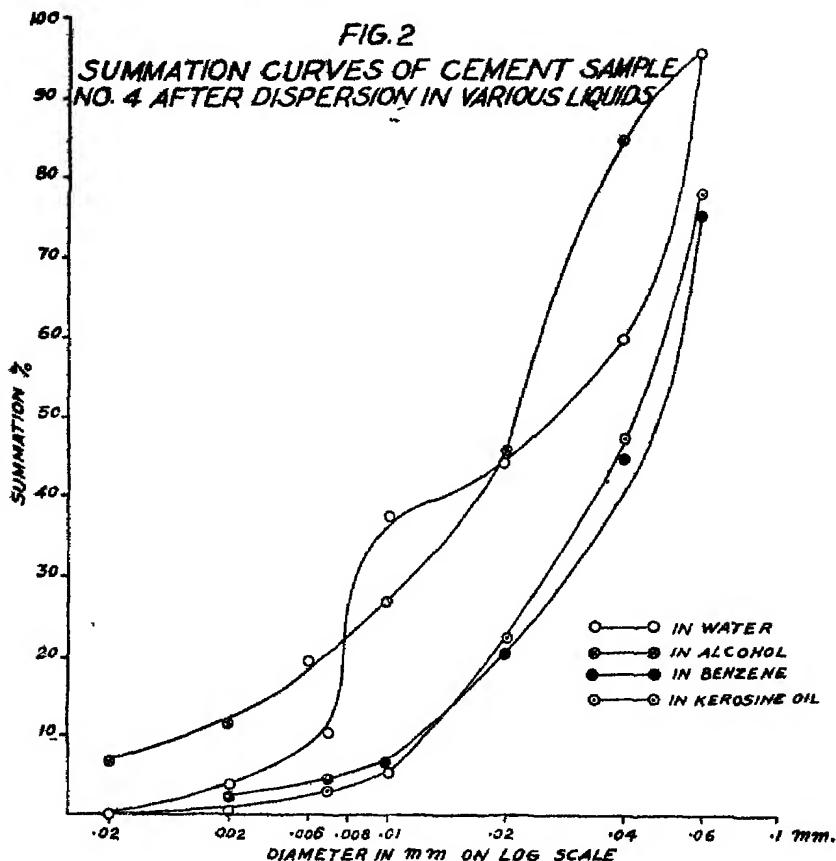


TABLE IV
MECHANICAL ANALYSIS OF CEMENT NO. 4 AFTER DISPERSION IN VARIOUS LIQUIDS
Summation percentages of particles of various sizes

Liquid	0.02 mm	0.04 mm	0.07 mm	0.1 mm	0.2 mm	0.4 mm	0.6 mm
In water	Nil	4.0	10.5	37.3	44.1	60.0	95.3
In alcohol	7.0	11.6	20.8	27.0	45.7	85.0	95.8
In benzene	Nil	2.1	4.5	6.8	20.6	47.2	75.5
In K. Oil	Nil	0.5	3.2	10.5	22.1	47.0	78.0

TABLE V.
MECHANICAL ANALYSIS OF CEMENT NO. 4 AFTER DISPERSION IN WATER FOR VARIOUS INTERVALS OF TIME.
Summation percentage of particles of various sizes

Time for Dispersion.	0.02 mm	0.04 mm	0.07 mm	0.1 mm	0.2 mm	0.4 mm	0.6 mm
For 12 hrs.	-	2.8	5.5	12.6	22.3	54.7	94.5
" 24 "	-	4.0	10.5	37.5	44.1	60.0	95.5
" 36 "	-	3.5	15.0	32.0	48.2	62.3	96.5
" 48 "	-	4.5	15.0	33.5	47.9	63.7	96.0

(2) Preliminary treatment of Cement to render it inactive towards water.

The changes that take place in cement on coming in contact with water are well known. They result in the aggregation of primary particles which cannot be broken down again. The first line of attack on this problem was to allow the water to act on the particles when they are already in a state of violent agitation

so that individual particles have no time to coalesce with one another. This is allowed to continue until the hydration is complete and the particles can no longer aggregate when the mechanical analysis can be done at leisure without fear of the particles forming aggregates. This object can be attained by shaking the cement continuously for 2½ hours with coarse sand or by boiling cement with

water when the violent agitation produced by boiling keeps the particles apart. After boiling the cement can be analysed mechanically in the usual way. Shaking with coarse sand has already been referred to and has been shown to be very effective in the case of cement No. 4. Other cements were analysed in a similar way. The results are given in Table VI. Effect of time of shaking was also studied and it was found that the minimum time of shaking is 24 hours after which there is very little increase in percentage of the finer fractions (Table V).

Violent stirring of cement No. 4 in water for different intervals of time by means of a mechanically rotating stirrer was also tried as a possible method of dispersion. The results are given in Table VII. It will be seen that this is nearly as effective as shaking with coarse sand.

Boiling with Water.

Boiling with water obviously is similar to shaking, with the difference that hydration might be brought about in a shorter time. Water was kept boiling vigorously and cement was added in small quantities (nearly half a gram at a time). Boiling was continued for varying lengths of time from 30 minutes to 10 hours.

The results given in Table VIII show that 6-8 hours boiling gives the maximum percentage of finer fractions. A comparison of Table V with Table VIII shows that 5-6 hours boiling is almost equivalent to 4-5 hours shaking with sand.

Cement contains about 60 per cent. lime and if an attempt is made to disperse it in water we get what in effect is a saturated solution of lime. The flocculating effect of calcium ions is well known and besides the aggregation produced by hydration, a large percentage of the finer fractions appear coarse on account of flocculation. It appeared that perhaps both the hydration and flocculation could be prevented if a part or the whole of lime could be precipitated as oxalate or carbonate. Increasing amounts of oxalic acid were added to cement No. 4 to neutralize increasing amounts of lime and the mechanical analysis was done with the pipette method as usual. The results given in Table IX show that when 30-40 per cent. of lime (practically 50 per cent. of the total lime) has been rendered inactive, the dispersion is at its maximum. The precipitation of lime could also be brought about by the addition of CO_2 in some form or another. CO_2 gas was passed through cement suspended in water and held in a sintered glass funnel. The rapid passage of CO_2 in minute bubbles through the porous disc kept the cement particles in violent agitation as it was in the case of boiling. It will be seen from Table X that even two hours treatment with CO_2 has not produced much effect and the mechanical analysis is the same as in water without any treatment.

Preliminary Treatment of Cement with water repellents.

Another line of attack on the problem of rendering cement inactive towards

water is to coat the particles with a substance like kerosene oil or wax that would "freeze" the particles in their natural state of aggregation and render further ingress of water impossible. In a preliminary examination kerosene oil was found to have no effect, the mechanical analysis of cement in water was the same after wetting with kerosene oil as without it (Table XI).

A sample of cement was next treated with increasing amounts of wax dissolved in benzene (5 c.c. of the solution of varying concentrations were used for 10 gms of the sample). On the evaporation of benzene a thin coating of wax was left on the particles. The results given in Table XI and plotted in Fig. 3 show that 4 per cent. paraffin wax solution gives the same state of aggregation as in kerosene oil. Similar results were obtained with cements 2, 3 and 4, the results of which are included in Table XII.

It is clear from these results that treatment with 4 per cent. solution of paraffin wax in benzene preserves the state of aggregation of cement as it exists in the dry state and which is also obtained by analysis of the untreated cement using kerosene oil as the sedimenting liquid.

A careful perusal of the results of mechanical analysis discussed in the foregoing brings out the interesting fact that the values fall under two groups, namely those obtained with non-polar liquids like kerosene oil (Table III) and also by coating with paraffin wax (Table XII) and those obtained in water or alcohol. In the former about 40 per cent. of the particles are coarser than .06 mm whereas in the latter not more than 10 to 12 per cent. fall in that category.

Dispersion of cement in water and alcohol, therefore, results in a greater disintegration of the compound particles than in non polar liquids which are not able to overcome the cohesive forces between the particles forming aggregates.

Mechanical analysis of any mixture of particles of various sizes can be referred to as "Aggregate Mechanical Analysis" and "Ultimate Mechanical Analysis". The former refers to sizes as they exist in the solid state including the compound particles as single units, the latter to ultimate sizes when all the aggregates and compound particles are broken down to primary units. Mechanical analysis in non polar liquids like kerosene oil and benzene or after treatment with paraffin wax refers to "Aggregate" analysis, whereas mechanical analysis in water after suitable treatment for disintegration must refer to "Ultimate" analysis. As to which of these two is likely to be of greater use in the practical interpretation of other properties of cement is more than what can be guessed at the moment. As a first approximation the "Ultimate" mechanical analysis must probably in the long run prove of greater fundamental importance than the "Aggregate" analysis, though the latter may have its use in comparing the results with "sieve" analysis which has been so far the standard method of expressing the percentage of particles of various sizes in cements.

TABLE VI
MECHANICAL ANALYSIS OF DIFFERENT CEMENTS AFTER DISPERSION IN WATER.
Summation percentages of various particles:

	.002 mm.	.004 mm.	.007 mm.	.01 mm.	.02 mm.	.04 mm.	.06 mm.
Cement No. 1 ..	Nil	2.5	16.8	37.0	43.0	59.3	95.0
Cement No. 2 ..	Nil	4.8	9.6	37.0	45.6	62.4	95.2
Cement No. 3 ..	Nil	5.2	11.2	36.5	46.8	61.7	96.4
Cement No. 4 ..	Nil	4.0	10.5	37.5	44.1	60.0	95.5

TABLE VII
MECHANICAL ANALYSIS OF CEMENT NO. 4 AFTER MECHANICAL STIRRING FOR DIFFERENT INTERVALS OF TIME.
Summation percentage of various particles.

Time of mechanical stirring.	.002 mm.	.004 mm.	.007 mm.	.01 mm.	.02 mm.	.04 mm.	.06 mm.
8 hours ..	Nil	2.7	6.1	22.8	45.4	68.1	95.5
12 hours ..	Nil	1.5	8.5	23.0	44.2	67.5	96.9
20 hours ..	Nil	2.5	8.9	23.5	45.9	69.0	96.9
30 hours ..	Nil	2.0	9.0	23.1	45.1	67.3	100.0

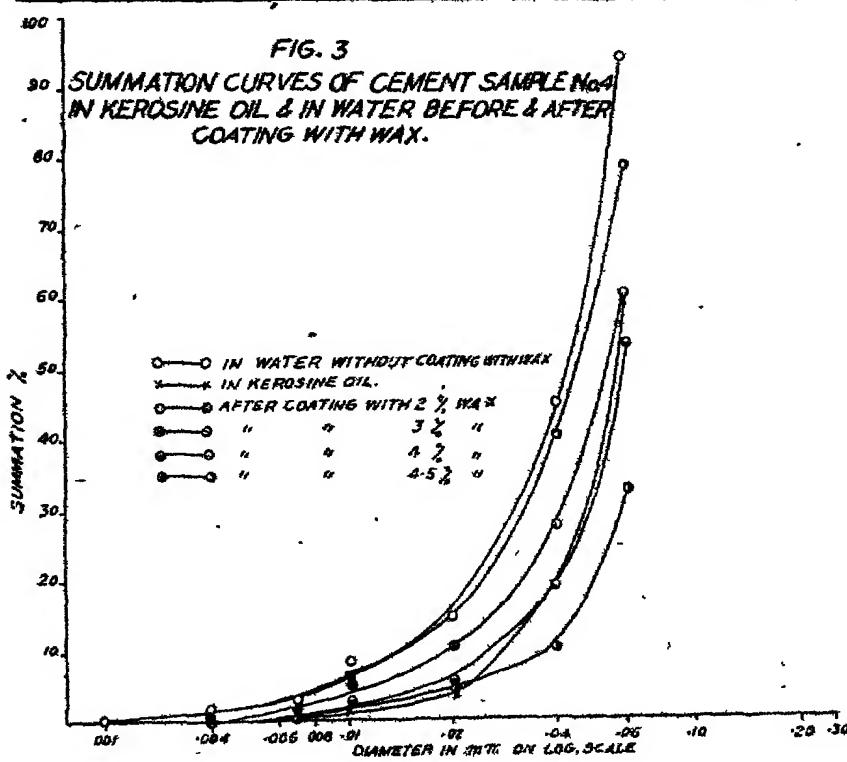


TABLE VIII.
MECHANICAL ANALYSIS OF CEMENT NO. 4 AFTER BOILING FOR DIFFERENT INTERVALS OF TIME.
Summation percentages of various particles:

Time of Boiling.	.002 mm.	.004 mm.	.007 mm.	.01 mm.	.02 mm.	.04 mm.	.06 mm.
1/2 hour ..	Nil	2.5	5.5	13.0	25.5	51.25	93.5
1 hour ..	Nil	3.5	8.0	15.4	30.3	54.5	94.0
2 hours ..	Nil	4.0	8.5	19.2	36.0	57.4	96.5
3 hours ..	Nil	4.5	8.0	24.7	39.2	58.0	94.5
5 hours ..	2.2	8.0	12.3	28.5	32.0	60.5	95.5
6 hours ..	3.5	10.0	16.0	37.5	39.0	62.0	96.0
8 hours ..	4.5	11.0	16.4	35.5	43.7	63.2	96.4
10 hours ..	5.0	9.7	15.3	37.1	43.0	63.8	96.8

TABLE IX.
MECHANICAL ANALYSIS OF CEMENT NO. 4 AFTER REMOVING DIFFERENT PERCENTAGES OF LIME WITH OXALIC ACID.
Summation percentages of various particles.

After removing.	.002 mm.	.004 mm.	.007 mm.	.01 mm.	.02 mm.	.04 mm.	.06 mm.
6% of CaO	Nil	1.0	4.8	9.3	18.0	30.4	97.0
12% of CaO	Nil	1.5	5.1	10.2	18.4	45.2	96.5
21% of CaO	Nil	1.0	3.4	9.7	64.4	72.0	97.2
30% of CaO	Nil	2.1	5.8	14.0	66.4	81.6	96.8
39% of CaO	Nil	4.1	7.2	13.7	66.0	81.0	97.3
48% of CaO	Nil	4.5	6.8	13.8	65.1	80.5	97.7
58% of CaO	Nil	5.1	7.4	15.0	64.9	81.3	96.9

TABLE X.
MECHANICAL ANALYSIS OF CEMENT NO. 4 AFTER PASSING CO₂ FOR DIFFERENT INTERVALS OF TIME
Summation percentages of different particles.

After passing for	.002 mm.	.004 mm.	.007 mm.	.01 mm.	.02 mm.	.04 mm.	.06 mm.
½ hour	Nil	1.0	2.9	10.4	22.8	43.5	95.5
1 hour	Nil	0.5	4.5	11.2	22.5	45.0	95.0
2 hours	Nil	1.5	4.2	11.8	21.5	46.1	95.5

TABLE XI
MECHANICAL ANALYSIS OF CEMENT NO. 4 AFTER WETTING IT WITH OIL AND COATING WITH DIFFERENT % SOLUTIONS OF PARAFFIN WAX IN BENZENE.
Summation percentages of various particles

	.002 mm.	.004 mm.	.007 mm.	.01 mm.	.02 mm.	.04 mm.	.06 mm.
In water ..	Nil	1.5	3.1	8.5	14.9	45.0	94.0
In kerosene oil ..	Nil	0.1	1.25	3.5	20.0	59.5	
After wetting with K. oil	Nil	1.4	3.7	7.0	21.5	49.5	91.5
Coating with 5% wax solution							
Aggregate was formed							
4.5%	Nil	0.25	1.5	4.5	10.5	32.5	
4.0%	Nil	0.2	3.0	5.5	19.5	53.0	
3.0%	Nil	1.5	5.5	10.25	32.5	60.0	
2.0%	Nil	1.0	3.8	6.5	15.0	40.5	78.5

TABLE XII.
MECHANICAL ANALYSIS OF DIFFERENT CEMENTS AFTER GIVING THEM A COATING OF 4% WAX SOLUTIONS.
Summation percentages of various particles

Sample of Cement.	.002 mm.	.004 mm.	.007 mm.	.01 mm.	.02 mm.	.04 mm.	.06 mm.
Sample No. 1 ..	Nil	Nil	0.75	2.25	7.0	21.25	55.5
Sample No. 2 ..	Nil	Nil	2.1	3.0	7.5	23.5	54.0
Sample No. 3 ..	Nil	Nil	1.4	4.2	6.5	28.5	59.0
Sample No. 4 ..	Nil	Nil	0.5	3.1	5.2	19.5	53.2

TABLE XIII
MEAN DIAMETER OF CEMENT SAMPLES IN VARIOUS LIQUIDS

Cement No.	Mean Diameter in kerosene oil		Mean Diameter in Benzene		Mean Diameter in alcohol	
	Mech. Anlys.	Capillari-meter.	Mech Anlys.	Capillari-meter.	Mech Anlys.	Capillari-meter
Cement No. 1 ..	0.0576	0.0593	0.0482	0.0472	0.0312	0.0310
Cement No. 2 ..	0.0618	0.0604	0.0478	0.0458	0.0308	0.0305
Cement No. 3 ..	0.0536	0.0576	0.0512	0.0482	0.0299	0.03007
Cement No. 4 ..	0.0555	0.0570	0.0480	0.0458	0.0306	0.0303

Expressing the results of mechanical analysis by "summation curves" or a set of values though much more comprehensive, has a tendency to complicate the issue in the sense that comparisons and correlations are almost impossible. While confronting a similar problem in the case of soils Puri* suggested that the mechanical analysis of such substances should be expressed in the form of "mean diameter" which is determined by multiplying the percentages of particles of various sizes interpolated from the summation curves with the corresponding particle size and dividing the sum of all such products by 100.

The degree of coarseness of a cement therefore could be expressed by calculating its "mean diameter" from the results of its mechanical analysis.

An alternative and rapid method of determining mean diameter of particles is to apply increasing pressure deficiency to a saturated column of sand, or soil etc until the capillary column breaks. If h is instance, is the pressure deficiency in cm when the break occurs and which represents the maximum capillary height, then by applying the well known formula for rise of liquids through capillaries, and substituting the various constants for water, it has been shown that $h = 1/D$ where D is the mean diameter of the particles. When other liquids are substituted for water, the modified relations are as follows —

Kerosene oil $D = 0.446/h$,
Alcohol .. $D = 0.397/h$, and
Benzene .. $D = 0.463/h$

Applying these relations and using different liquids the mean diameters of the cement particles in all the four cement samples were determined. The values along with those determined from the results of mechanical analysis are given in Table XIII.

The agreement of values obtained by the two methods is fairly close, and as expected the values are largest in kerosene oil and smallest in alcohol.

For comparison of different cements, this "Single Value" should prove of greater utility than a set of values expressing the percentage of particles of various sizes.

SUMMARY.

The importance of determining mechanical analysis of cements is discussed and the results obtained by employing the principles of sedimentation, using different liquids as sedimenting columns, are described. The mechanical analysis in kerosene oil represents the actual state of aggregation of particles and may be described as the "Aggregate Analysis".

The aggregates can be dispersed into ultimate primary units by shaking with coarse sand in water for about 24 hours or boiling in water for 6 hours. The cement particles then do not get flocculated in water and the mechanical analysis, which may be called the "Ultimate Analysis" can be determined by using water as the sedimenting liquid.

(To be continued)

* Puri, A. N., and Puri, B. R.—1939—Expressing Mechanical Analysis state of aggregation of soils by single values—Soil Sci. 47 77

SHELL CONCRETE CONSTRUCTION

[By Dr. K. HAJNAL-KONYI, M.I.Struct.E.]

Continued from Previous Issue

Part II. Domes.

I. Introduction.

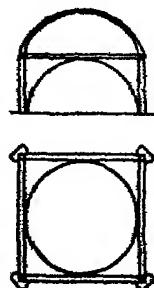
The application of shell construction revolutionized the building of domes as much as that of vaulted roof construction. The building of domes is one of the oldest problems of architecture. The earliest domes were of the shape of surfaces of revolution. They may be regarded as ancestors of the modern shell construction, since they transmit load in three dimensions. They are, however, not "shells" in the modern sense, because their thickness is very great in relation to their span.

The spans of some of the old domes are surprisingly large. The Pantheon in Rome, erected in the first century A.D., has a clear span of 140 ft. In 1800 years it has required only a few minor repairs, and the building which it covers still serves as the burying place of the kings of Italy. The span of the Pantheon was not reached in any of the later domes, built in solid material, until the introduction of reinforced concrete. Only in our century has this span been exceeded. Shortly before the last war a dome of 213 ft. span in reinforced concrete was completed at Breslau.

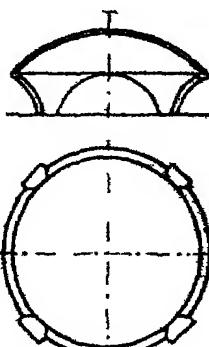
In the middle ages the ribbed dome was developed. In this the loads from

the "shell" are transmitted to the ribs which transfer them to the supports. Most of the big domes of later date (e.g., Florence, St. Peter's in Rome, St. Paul's, Breslau) are of this type.

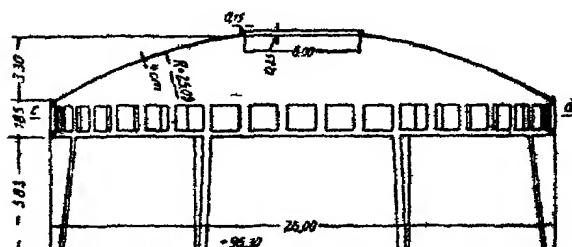
Such domes are suitable for churches, monuments and the like. For industrial buildings, with rectangular plan, they are of no importance. It is, of course, possible to transfer the load from a surface of revolution to a square, e.g., in the way of a Byzantine cupola (Fig. 27). This is done by four main arches over the sides of the square to which the weight of the dome is transferred but the dome is supported directly at four points only, i.e., at the crowns of



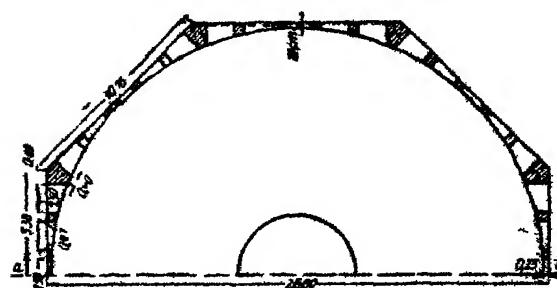
27. The Byzantine cupola.



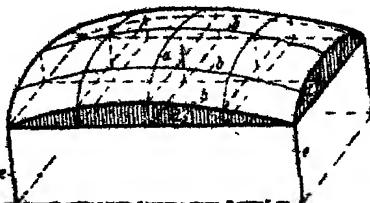
28. The dome of 213 ft. span at Breslau.



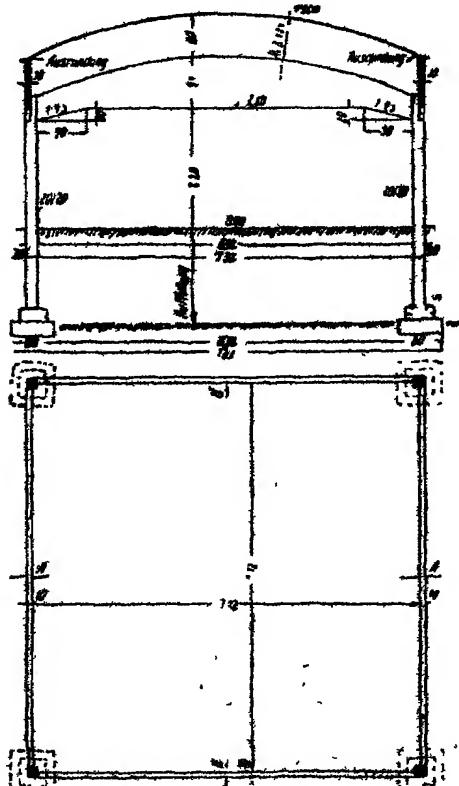
29. Section through the dome of the electricity works at Frankfurt which has a 11 ft. rise on a 85 ft. span with a shell 1 1/2 in thick.



30. Half-plan of the building shown in Fig. 29. (Section c-d)



31. Diagram showing the principle of covering a rectangular area with a shell roof curved in both directions.



32. Plan and section of a model illustrating the principle shown in Fig. 31. The area covered is 24 ft. by 24 ft. with a shell 1 1/2 in. thick increased to 1 ft. at the edges.

the four arches, and all the rest has to be transferred by pendentives, which are very heavy and complicated.

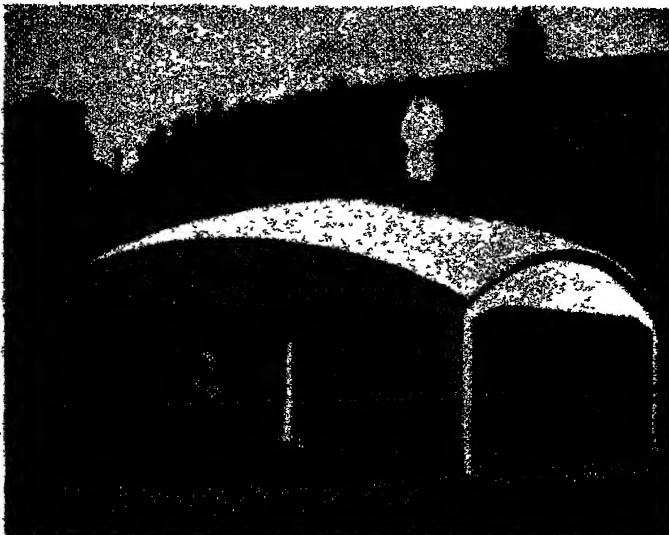
The shape of building adopted at Breslau (Fig. 36) is also confined to monuments. The four main arches are not plane; they are in the surface of a vertical cylinder of the same diameter as the ring of dome. The dome is continuously supported on its whole perimeter and the pendentives are omitted,

but the main arches must be supported laterally. At Breslau this was done by four apses.

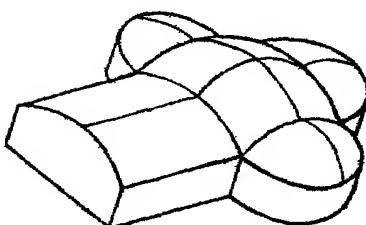
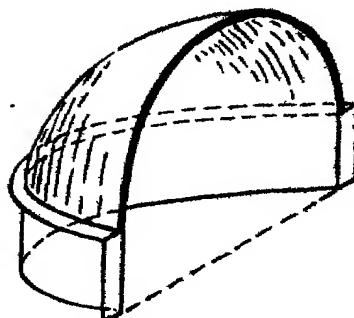
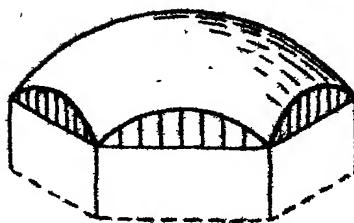
The following examples illustrate the advantages of the Zeiss-Dywidag system of construction over the traditional forms

2. Examples

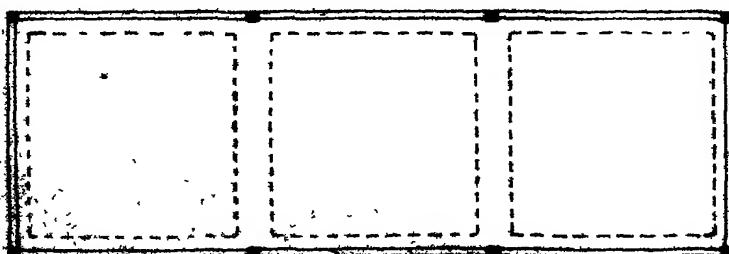
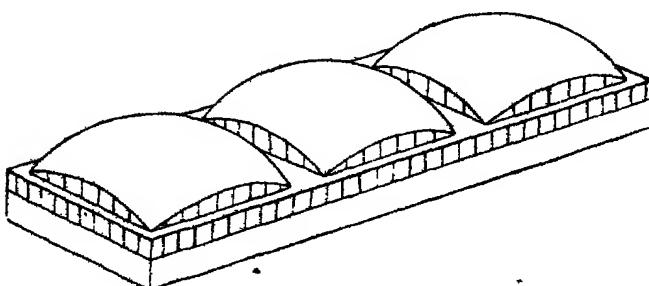
The simplest form of reinforced concrete dome is a spherical shell. The



33. The actual model shown in Fig. 32. Fifty people are standing on the shell



35, 36, 37 Three further examples in diagrammatic form.

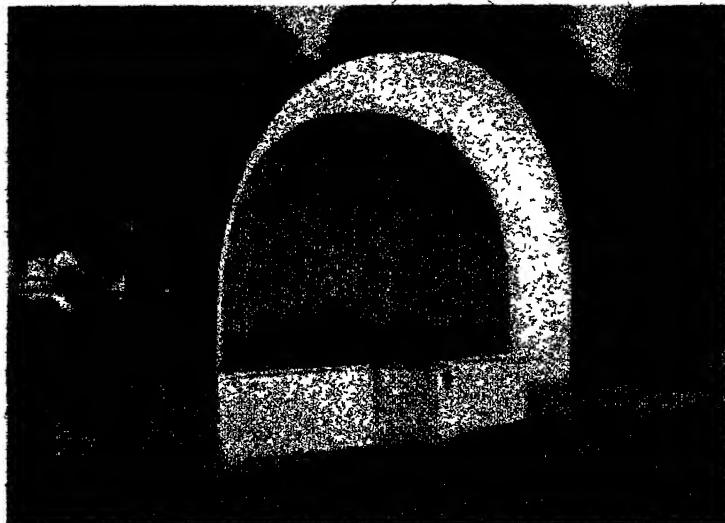


34. Diagram in plan, elevation and isometric of the type of dome structure possible in shell concrete.

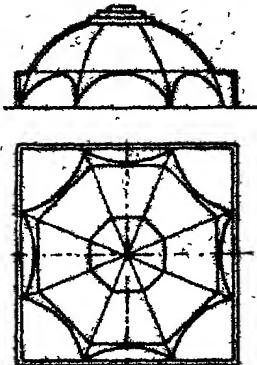
dome shown in Fig. 29 was built in Frankfurt-on-Main in 1928. It is remarkable for its flatness. Its rise is only 11 ft. on a span of 85 ft. The shell is only $\frac{1}{7}$ in. thick, i.e. $\frac{1}{10}$ of the span and $\frac{1}{12}$ of the radius of curvature. Its factor of safety against buckling has been determined by testing a model; it is 8.8 when the dome is fully loaded. The shell is comparatively thinner than an egg shell. The dome is supported on a Vierendeel* girder which rests on eight columns. The inner face of this girder is circular, the outer face is octagonal, its width is minimum in the centres of the spans, maximum at the supports (Fig. 30). This is a very favourable form of a Vierendeel girder, because the shear stresses are reduced at the critical sections.

The problem of covering areas of rectangular shape can be solved in reinforced concrete shell construction by a surface curved in both directions, formed by a generating curve, which is moved along another curve (Fig. 31). Fig. 32 shows a model of this type. The area covered by the model is 24 ft by 24 ft and the thickness of the shell is only $\frac{1}{12}$ in., which is increased to 1 in. at the edges. This model was loaded with 61 lb/sq. ft (a) over the whole area,

* Belgian system with panels without diagonal bracing.



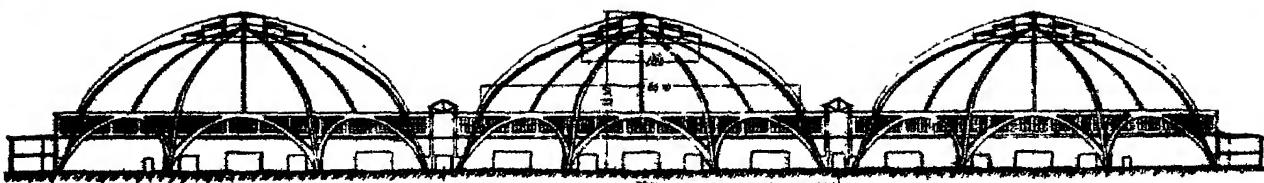
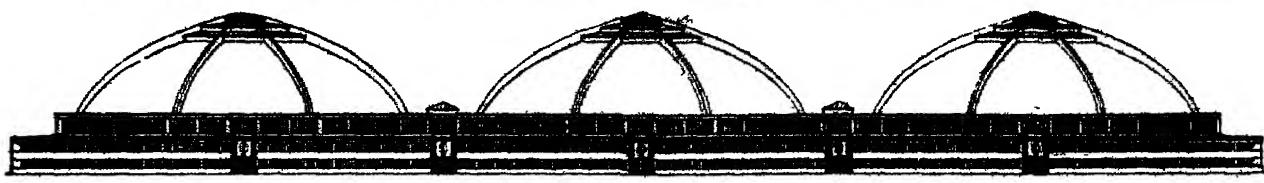
38. A bandstand at Bad Homburg in shell concrete, of a type shown in diagrammatic form in Fig. 36.



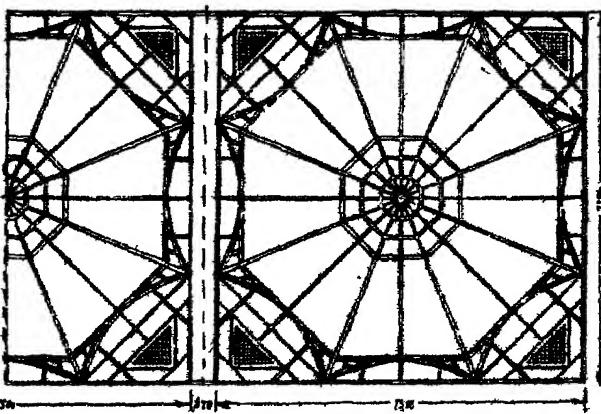
39. Diagram showing another development in shell concrete of a polygonal dome formed by the intersection of cylindrical shells which covers a square.



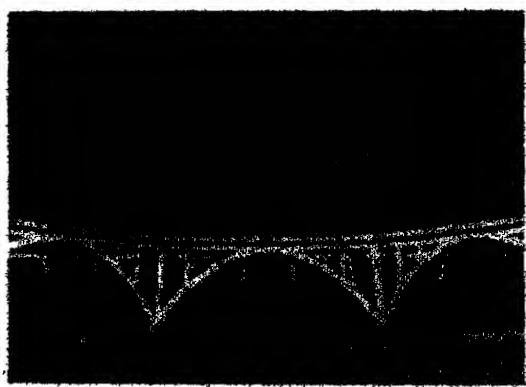
40. Model and view of the exterior of the Market Hall, Leipzig, with its three octagonal domes. The building covers an area of 21,500 sq. yds., each dome having a span of 248 ft. There are only four pairs of columns within the whole rectangle. The shell thickness is $3\frac{1}{2}$ in.



41. Elevation and section of the Market Hall, Leipzig.



42. A plan of one of the domes at the Market Hall, Leipzig, looking up.



43. An interior view of the Market Hall, Leipzig.

(b) on one-half only. When the whole area was loaded the maximum deflection at the crown was less than $\frac{1}{5}$ in. No cracks occurred under this load. The behaviour of the model when the load was applied on one side only was equally favourable. In Fig. 33, 50 people are seen standing on the model. Figs. 34 to 37 show a few possibilities of this type of structure, Fig. 38 a practical application of the form of Fig. 36.

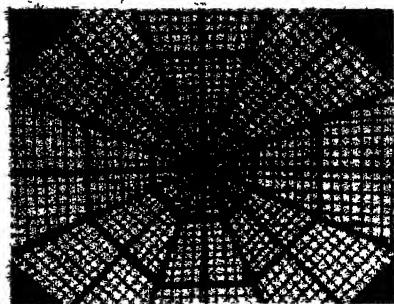
Another line of development is that of polygonal domes formed by the intersection of cylindrical shells. For covering a square, an octagonal dome, obtained

from four cylindrical shells, is particularly suitable (Fig. 39). Two columns are arranged on each side of the square, and it is a simple matter to cover the remaining areas at the four corners by a flat roof. The whole area of the square remains free of columns.

The ridges, formed by the intersection of the shells, replace the rigid frames in barrel vaults. In the case of barrel vaults substantial bending moments are developed in the frames, whereas in symmetrical polygonal domes these bending moments are eliminated by horizontal forces acting in "ring" tension.

From the static point of view, this type of dome structure is a combination of two systems, the cylindrical shells acting as girders, and a system of horizontal forces similar to the "ring" tension in a dome of traditional shape. The excess of the horizontal forces in this structure over those occurring in the traditional design increases as the number of columns decreases. The remarkable feature of the system is the absence of bending moments in the ridges, not only for symmetrical loading (dead weight and snow) but even for wind.

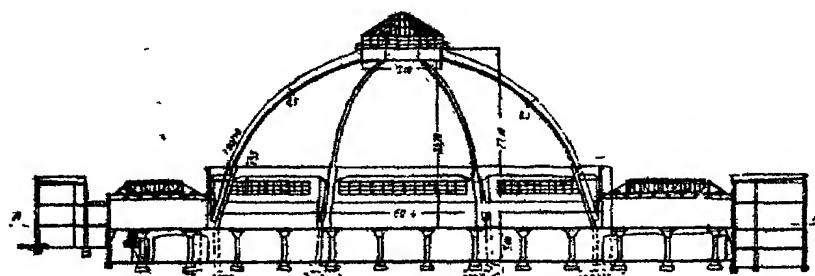
The largest example of octagonal



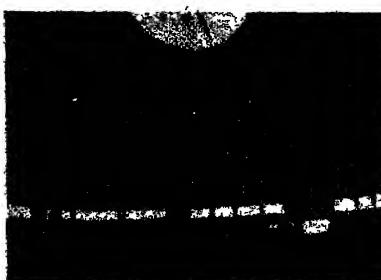
44. One of the lantern lights at Leipzig Market Hall.



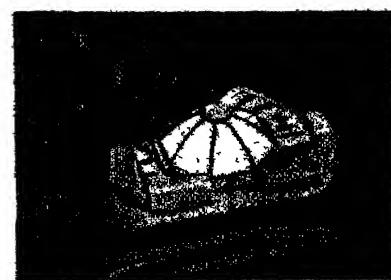
45. Another interior view at Leipzig.



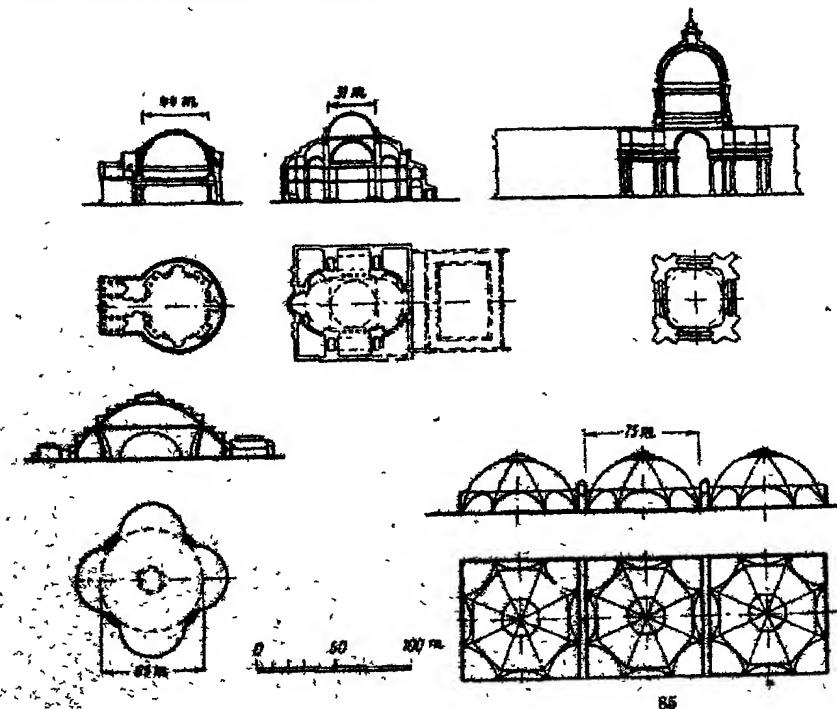
46. Section through the cupola of the Market Hall, Bielefeld. Diameter is 197 ft and the cycloid shell is 3½ in. thick.



47. An interior view of the Market Hall, Bielefeld.



48. An aerial view of the Market Hall, Bielefeld.



domes is the Market Hall at Leipzig (1929, Figs 40 to 45). The building covers an area of 784 ft by 248 ft, i.e., 21,500 sq yds. This area is roofed by three domes of 248 ft span, with only four pairs of columns within the whole rectangle. Each dome has a roof light of 92 ft. diameter (Fig. 44). Further roof lights are arranged across the building between the domes and in the corners covered by flat roofs. The cylindrical shells forming the domes are of elliptical shape, the radius of curvature at the crown is 150 ft, and in the direction of the ridges 177 ft. This is the maximum radius of curvature of any dome ever carried out in steel or concrete. The span in the direction of the ridges is 267 ft, the thickness of the shell only 3½ in.

In order to increase the safety of the

(Concluded on pag. 88)

49. A scale comparison of a few famous examples of domes throughout the ages shows the significance of shell concrete construction. Top, left, the Pantheon. Top, centre, St. Sophia (A.D. 532-537). Top, right, St. Peter's, Rome (A.D. 1306-1626). Bottom, left, the Feschialle, Breslau. Bottom, right, the Market Hall, Leipzig.

PRECISION FORMS MEET CLOSE TOLERANCE NEEDS OF CONCRETE WIND TUNNEL

EXTREME ACCURACY of concrete work was achieved by The Austin Co., in constructing for the Boeing Aircraft Co., of Seattle, Wash., a wind tunnel for aerodynamic research involving air velocities as high as 700 mph. Tolerances of $\frac{1}{16}$ in. were maintained in the bellmouth of the 450-ft. long continuous return reinforced concrete tube of approximately rectangular cross-section by ingenious design of precision forms. At the test section or throat, the tunnel is 12×8 ft., with 2-in. corner fillets. From here it increases in size to the first corner, where the dimensions are 20×20 ft.; it is the same at the second corner. At the nacelle, which encloses the power plant and huge motor-driven fan, it changes to a circle of 24-ft. dia. Approximately 100 ft. from the nacelle, the cross-section increases to a maximum of $27\frac{1}{2} \times 27\frac{1}{2}$ ft. In a length of 25 ft., the size is again reduced to 12×8 ft. at the test section.

Bellmouth Formwork.

As the tolerances for the construction of the concrete from the bellmouth through



PRECISION FORMS are erected for 450-ft. long reinforced concrete wind tunnel. Tolerances of $5/16$ in. are permissible in this area, as compared with $1/8$ -in. tolerances in bellmouth and test area, forms for which are in place in right background.



HEAVY BRACING is required in form work around test section, demanding $\frac{1}{16}$ in. tolerance.

the diffuser section were confined to very close limits, with a permissible variation of $1/16$ in. either way from the true dimension, considerable study was given to the formwork for the bellmouth. At various stages consideration was given to building the bellmouth oversize and putting on a plaster finish to the exact close dimension. At another stage, wood was considered in several different forms. One idea was to bend narrow strips of wood to the desired form and another was to build the form out of heavy laminated wood and then adze the form to the proper shape.

It was finally decided to build the inner form in a vertical position out of metal lath and plaster. This form was constructed in one piece, heavily braced, and was tilted from a vertical to a horizontal position. After the reinforcing steel for the walls of the bellmouth was in place, the exterior form was built. The floor was poured first, together with the side walls up to the floor of the



MODEL AIRPLANE is mounted on special balances in test chamber of Boeing wind tunnel. Removable walls and ceiling cannot be distinguished from concrete tunnel itself. Small holes in walls, floor and ceiling are used to test air pressure, while vanes, made of 12-gauge Armco ingot iron and extending from floor straight wall, aid measurement of wind velocity.

test section and the remainder was poured in a later operation. The fillets in the entrance to the bellmouth, which were approximately 6 ft. measured along the centre line of the tunnel, were built of wood covered with metal lath and plaster fitted against the shoulders of the walls, floor and ceiling.

From the diffuser section through the four corners to the bellmouth, the tolerance permissible in the formwork was $5/16$ in. from the required dimension. The great variety of changes in sections and changes in fillets presented a constant problem in building the formwork, particularly fore and aft of the fan, where the sections change from rectangular to full circular and back to rectangular again.

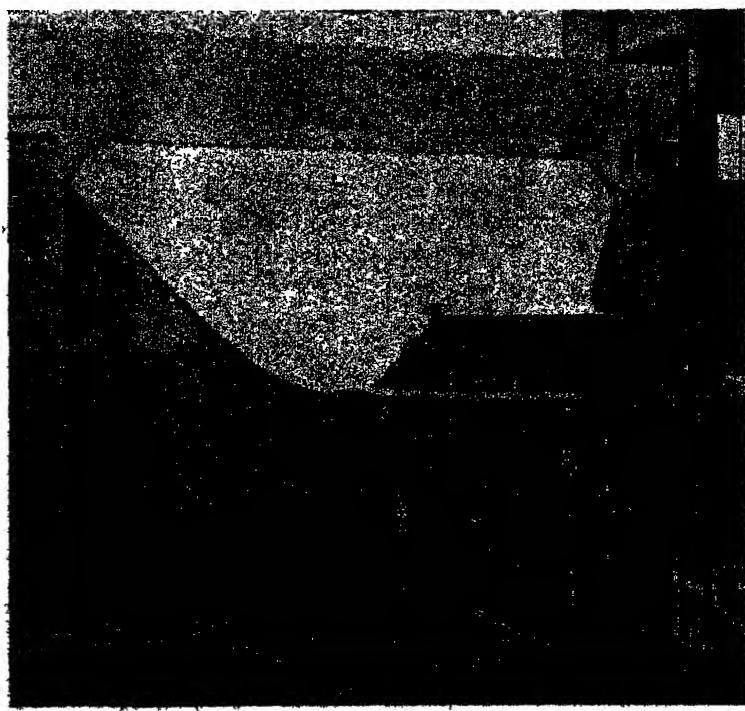
The wind velocities vary from a maximum of 700 mph at the test section to approximately 80 mph at the third and fourth corners. The pressure at the test section under maximum wind velocity is 1,000 lb per sq. ft. A steel pressure cap was, therefore, designed to enclose the test section. The skin of this cap is $3/16$ -in plate reinforced with tees placed approximately 18 in. on centres. The tunnel's air flow is created by a 24-ft dia propeller-like fan located at the nacelle. A Westinghouse motor of 18,000 hp driving a 14-in solid steel shaft at 514 r.p.m. is the power unit for the fan, which consists of 16 laminated spruce blades built and designed by Boeing engineers.

Allallowance for Concrete Expansion.

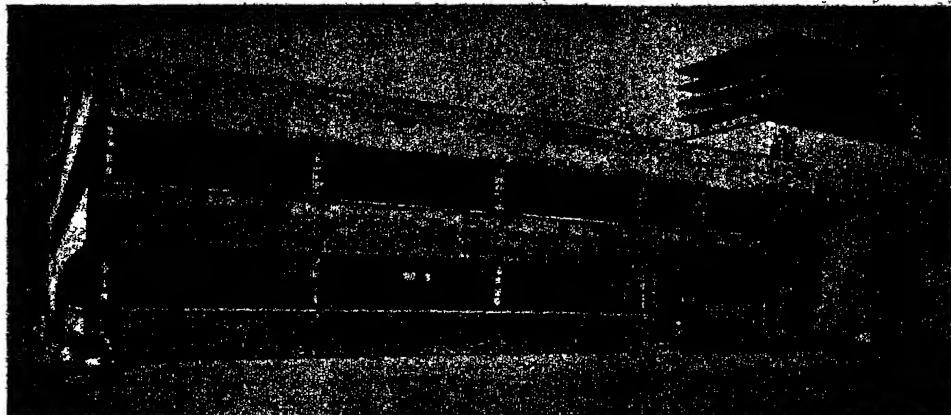
The tunnel is divided into a number of sections to take care of expansion of the concrete due to a 70-deg. variation in temperature. Certain of the joints are designed to take a pressure of 150 lb. per sq. ft. inward and 250 lb. per sq. ft. out-

ward. At one time rubber filler or wedging pieces were considered, but as it was not possible to get a positive connection between the concrete and the rubber, this idea was abandoned.

The forward part of the nacelle is constructed of 12-gauge metal skin fastened to bent angle rings. Access doors are provided so that an observer can watch the operation of the fan. The



INNER FORM FOR BELLMOUTH is built of metal lath and plaster, heavily braced on inside, with heavy coat of lacquer and two coats of heavy wax given to plaster surface to make it smooth and waterproof. Erected on end in one piece, it was tilted into horizontal position as shown here, when entirely complete.



MODEL SHOP. Offices, drafting rooms and operations area are housed in two-story reinforced-concrete building which houses test is isolated from wind tunnel. Dark-coloured cement was used in interest of camouflage and paint conservation. Pagoda-like structure above tunnel (right) houses air interchanger. Laboratory is completely isolated from tunnel by expansion joint extending through floors, walls and roof. Continuous bands of wood seal extend around building.

rear portion of the nacelle is of wood built up on laminated plywood ribs and it is supported fore and aft of the fan by steel struts which are encased in fairings of 12-gauge sheet metal.

To move in equipment and for general access, a number of doors were provided into the tunnel. They had to be flush on the inside with no hardware protruding from the face. Some of the doors had to be designed for inward pressure, others for outward, and others for both inward and outward. In general they were built of wood framed with steel and sealed with rubber gaskets and special locking devices to prevent chatter.

Model planes with wing spreads up to 11 ft. or full-scale airplane sections of the same maximum size can be tested in the tunnel. All tunnel controls are centralized in the panel board before the test section, at the same place where model observations are made. The tunnel is sound-proofed throughout and even its highest speed operation is scarcely audible in adjoining quarters.

Building Isolated from Wind Tunnel.

The building in connection with the wind tunnel, which is to be used for model shop, operations room, offices and

drafting rooms, was isolated from the tunnel itself by an expansion joint that extends through floors, walls and roof. The entire building and tunnel were built on piling driven to 40,000-lb. bearing capacity with piles approximately 3.5 ft. long. The foundation of the test section was again isolated from the supports of the tunnel itself and a group of 16 piles were driven to support the balancing equipment under the test section and to permit the reading of the delicate instruments that might be subjected to vibration by the operation of the tunnel.—(With acknowledgments to "Construction Methods.")

(Continued from page 85)

shell against buckling, a rib, which is not visible at the outside, has been arranged to project on the inside of the shell in the middle of each panel. Although it would have been possible to transfer the whole load by the shell directly to the columns, without supporting arches, such arches, supporting the flat roofs, have been provided for architectural reasons. Fig. 45 shows the inside after completion.

Another notable example is the Market Hall at Basle (Fig. 46). Its diameter is 197 ft., and it is remarkable for the omission of the supporting arches (Fig. 47). This omission governed the shape of the shell which is a cycloid. Its

thickness is 3½ in. No stiffening rib on the inside was necessary. Fig. 48 is an aerial view of the building.

The significance of shell construction for domes may perhaps be best realized by comparison of various famous examples. Fig. 49 shows the sections and plans of five large domes, to the same scale. The weights of three of them are as follows:

	Diameter. ft.	Weight. tens.
St. Peter's, Rome ..	131	10,000
Breslau ..	213	6,340
Leipzig ..	248	2,160

Thus the total weight of the three domes at Leipzig is approximately the same as that of the dome at Breslau,

and less than two-thirds of the dome of St. Peter's in Rome.

Many of the buildings described in this article are in areas which have been exposed to heavy bombing. Information about their behaviour which will be available after the war should shed interesting light on the resistance of such structures to shock, blast and the like.

The limits of space do not allow the reproduction of more examples of the Zieg-Dywidag shell system. It is hoped, however, that the information given in this article will enable architects to realize the possibilities of this system. It has opened a new chapter in the history of architecture.—(With acknowledgments to "The Architects' Journal.")

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PROCESSING SOIL-CEMENT LANDING MAT AT OTTUMWA NAVAL AVIATION BASE

IT was a race against approaching winter. The dead line was to be December first—whether or no. There was only October and November remaining to complete the octagonal landing mat, 2,310 ft long and 1,956 ft. wide (4,365,516 sq. yds.) at the Ottumwa, Iowa Naval Reserve Aviation Base. The choice of material had been a 6-in. depth at soil-cement.

The only suitable level ground in the vicinity of the Air Base had, for years, been complacently devoted to farming. The soil was as black as it was fertile—

ing. The piles were later levelled with bulldozers and motor graders and finally struck off to an exact surface by means of a wood float, reaching from form to form, and pulled by two crawler tractors

Cement was hand-spread, and on the day of the maximum run required 3,466 bbl. In processing, 12 per cent cement by volume, 0.54 bags per square yard of 6-in. compacted depth, was used.

Once the cement was spread by hand transversely, it was evenly distributed longitudinally with flattened spike-tooth harrows. Usually processing was started

all mixing equipment moved in trains, each unit occupying a definite numerical position in the train and so spaced transversely that each type of equipment equally engaged the entire 12½-ft cross-section with each passage of the train.

Two heavy duty spring tooth field cultivators took the lead. It happened that these were 9 ft and 8 ft in width, respectively. The first in line occupied the position adjacent to the form or completed edge, the second in line occupied the position adjacent to centre line. Obviously there was some overlap.

The next units in the train were three gang plows. The one in the lead occupied the position at the extreme right. This unit consisted of three bottoms with 14-in. mould boards each. The two others had three bottoms each but with 16-in. mould boards. The second plow unit engaged the middle third while the last in order worked at the extreme left of the 12½-ft sweep. Had five-bottom gang plows been available, two such units would have sufficed, thus effecting a saving of one tractor, one operator and one attendant.

Next in the train came three self-powered rotary tillers each 6 ft in width and so spaced that they engaged the right, the middle and the left thirds, respectively, of the 12½-ft sweep.

The form plow and the gang plow with 14-in. mould boards were powered each with 23-hp pneumatic-tired tractors. All other mixing units were powered with 35-hp crawler tractors.

The form plow was a single-bottom unit with 16-in. mould board. This was especially fitted with depth gauge to ride and clean the form or completed edge.



Three-bottom gang plow and three rotary speed mixers in action during moist mixing operations.

much less suitable for being converted economically into soil-cement than into Iowa tall corn. As a result, the economical answer was found by using soil for processing which was transported from the Des Moines River flood plain 10 miles distant.

This soil was a grayish-brown sand ranging between 0.005 mm. and 2.0 mm. in grain size, hence was readily workable.

The subgrade was levelled off and compacted first with sheepfoot tampers and then with flat-wheeled rollers. In drier weather, the base would have been ideal. As the season advanced, however, the delays from cold and wet weather became chronic.

For the processing it had been decided to use mixed-in-place methods and to work in alternate lanes 25 ft in width each. The lanes were defined by 6 x 6-in., or 8 x 6-in. wooden forms. Since there was a shortage of either sized timbers alone, both sizes were used. The timbers were notched so as to dovetail for a length of 1 ft. at the ends. Forms were held rigidly to line and grade by means of steel pins.

The sand, lane by lane in prescribed amount, was end-dumped from trucks on the subgrade in advance of process-



Mixing train completing mixing operations on one processing lane followed by sheepfoot roller starting preliminary packing on the adjacent processing lane.



Pneumatic-tyre tractor, with finger weeder attachment removing surface compaction planes left by sheepfoot rollers.

also with a wing extension on the mould board to rake the soil-cement over about 3 ft from the edge. The form plow operated continuously and independently of the mixing train. Thorough mixing adjacent to the form on the finished edge required six passages along each edge during processing.

Following the spread of the cement the mixing train proceeded. To prevent raw cement being turned under to subgrade, the first round trip of the train

was made without the gang plows. In this preliminary train all other units in the order mentioned, were intact; the machines maintaining the same numerical positions and holding to the same half lane on the outbound as well as on the inbound passages. This procedure incorporated all raw cement into the top 4 or 5 in. of the soil.

When the train started its second round trip, all units, including the gang plows, occupied their prescribed places.

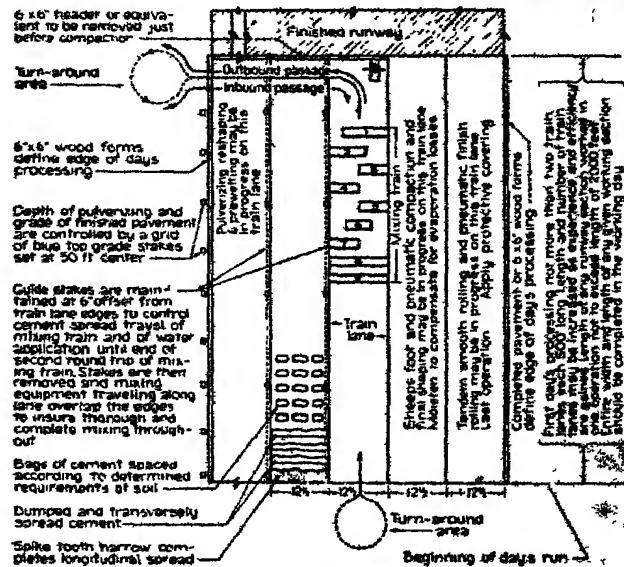
The plows cut evenly to subgrade and defined the specified depth of 6 in. while the cultivators and tillers completed the mixing of any raw soil the plows may have brought to the surface. Thus with each outbound and inbound passage of the train, all the soil-cement within the area of the half lane was subjected to the mixing action of the three types of machines in turn—cultivators, gang plows, tillers—each supplementing the other with the type of mixing characteristic of it.

The sandy soil did not require pulverization, hence no extra trips for this purpose were required.

After the preliminary turnover, two round trips with the entire train were required to give a thorough mix. This meant four additional complete passes of each of three types of mixing action over any given cross section of the area being processed, or a total of 16 separate agitations. The method gave assurance that each unit of area received the same degree of thoroughness of mixing.

By the time the first half lane was mixed, cement spread on the second half had usually been completed. The machines then immediately started on the second half. The cultivators and tillers following along centre line were required to overlap the other half by 1 or

SOIL-CEMENT "TRAIN" PROCESSING AIRPORT RUNWAY CONSTRUCTION, IN TRAIN LANES EACH 12½' WIDE Successive train-lane method



Preparation of Runway for Processing
First the runway section is graded to line and grade requirements in consolidated section. All such grading must be completed before pulverizing and processing operations over the entire edges of runway and lanes to be pulverized are defined with guide stakes in the same manner as for processing. A section is then located and pulverized to 5½-inches deep. Road roller, scrapper or motorized road grader, plow, etc., as needed, should do all dry soil and hard material removal for rough leveling by repeated water applications, which are preferable to seek out the soil by hand. Mechanics of 30-ton motorized mixing train to be concentrated on some soils as part of running operations after completion of mixing. The day before processing sufficient water is applied on the section and turned 10 to 12 ft. 3 to 6 water applications per lane during processing operations will furnish water requirements. The section is then leveled prior to cement spread. After cement is spread on a lane, start the routine of mixing by train method.

An experienced efficient crew can build 6 12½' lanes 3000 ft long in 12-hour period with equipment listed provided no time is lost on cement spread or larger applications. One day's work by such an organized crew will complete a runway 6000 feet long and 12½' wide as shown by contractors who have exceeded this production.

Mixing Train Units

Unit	Description of Unit	Motive Power
1 1 18	Cultivator Heavy duty Springtoom fitted with 4 double pointed chisel	Tractor Crawler type Min. 35 D.B.H.P.
2 1 18	Cultivator Heavy duty Springtoom fitted with 4 double pointed chisel	Tractor Crawler type Min. 35 D.B.H.P.
3 1 56	Plow Tractor, Heavy duty 5-14 bottoms (culti coulters)	Tractor Crawler type Min. 35 D.B.H.P.
4 1 56	Plow Tractor Heavy duty 5-14 bottoms (culti coulters)	Tractor Crawler type Min. 35 D.B.H.P.
5 1 6	Rotary Speed Mixer, self-powered	Tractor Crawler type Min. 35 D.B.H.P.
6 1 6	Rotary Speed Mixer, self-powered, trailer mounted	Tractor Crawler type Min. 35 D.B.H.P.
7 1 6	Rotary Speed Mixer self-powered, trailer mounted	Tractor Crawler type Min. 35 D.B.H.P.
8 2 24	Distributor Water Pressure 1000 gallons	Self-powered
9 1 12	Harrow Spike tooth 3 sections	Tractor Rubber-tired Min. 23 D.B.H.P.
10 1 6	Cultivator Chisel Power control (Attachment to tractor)	Tractor Rubber-tired Min. 23 D.B.H.P.

Routing of Mixing Train

First round trip—Use cultivators (Units 1 & 2) and mixer (Units 5, 6, 7, 8). These machines otherwise to maintain same relative positions each passage. Second round trip—Use entire train as shown. All machines to maintain same relative positions for about ½ of water requirements on outbound & ½ on inbound passage. Third round trip—Use entire train as shown. Add remaining water needs. Fourth round trip—Use entire train as before. Add remaining water needs. IF TOTAL WATER NEEDS CANNOT BE ADDED DURING FOUR TRIPS, CONTINUE ENTIRE TRAIN UNTIL ALL WATER IS ADDED.

Second round trip—Run only to complete uniform water distribution to mat or to complete water addition requirements. Mixing train then moves to next train lane. Sheepfoot compaction may start on any train lane as soon as the mixing train has finished. There should be no traffic intermixing.

- (1) A second cultivator (fixed angle) as auxiliary to replace unit 1 on inbound passage, or if desired, to follow unit 2 (culvator) in mixing train. Spacing may be according to the full width of the train lane.
- (2) Unit 1 (culvator) completes mixing adjacent to previously finished pavement surface independent of mixing train. Hand plow, tiller, supplement mixing near header, keep cuts even, removes any raw soil from mats, and return mats to concrete to section.

Notes:
On days that require processing in alternate lanes 12½' wide and denoted by 6 ½' wide forming a general form, a 23 D.B.H.P. tractor should be added to the equipment on site. The power should be selected based upon energy and driving resistance of the load. Larger or smaller units may be used, however, to meet the requirements of the job. The mixing train should be run in the direction of the prevailing wind to reduce dust.

Chart shows technique used in "train" soil-cement processing



A view of mixing tram following pressure distributor during moist mixing operations.

2 ft., thus blending the mix of the two half lanes.

Since this method of processing left no dead-furrows or back-furrows or other displacements of material, no levelling off with motor grader in advance of compaction was ever required. Immediately after the last round of the mixing equipment, the sheepfoot rollers entered the fresh mellow bed of processed soil-cement with the tamping feet at first readily penetrating to sub-grade. Tamers were therefore working on the first half lane while the mixing train was on the second.

Equipment for moistening consisted of four one-thousand gallon pressure distributors each having a spray bar to cover $12\frac{1}{2}$ ft. of width. Because of the friable soil all distributors were towed through the soil bed with crawler tractors

The operation of moistening began the day before processing. Enough water was added at that time to bring the soil to such condition that, during processing the next day, only three to five tanks, 3,000 to 5,000 gal. per $12\frac{1}{2}$ ft. width, would be required. By this method the distributors could bring up

the rear of the mixing train without causing disorder or delay. A distributor was held in waiting to follow the first outbound passage of the full train; that



Large pneumatic-tyre roller used during smooth rolling operations.

is, after the first turgovery with the plows Pressure was gauged to distribute the entire tankful, or as much as necessary, over the entire length of lane.

lane) reduced evaporation losses to a minimum.

3. As in a modern defence plant, each operator realized he was part of a production line and that he must synchronize his performance to the moving train. His was a definite link in the chain.

4. Since all machines were moving at the same time, there was no confusion or lost time and no displacement of materials due to turnouts en route.

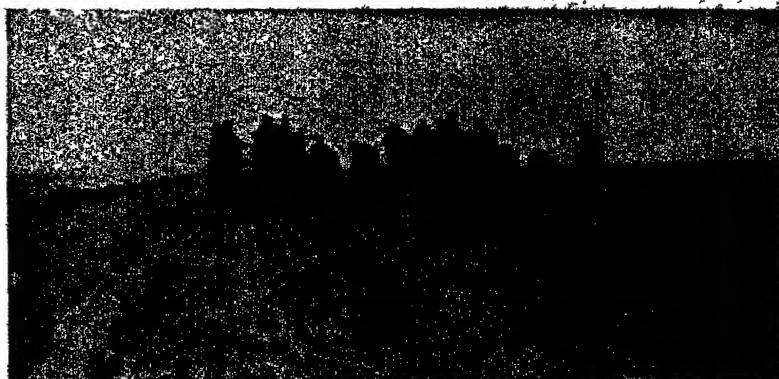
5. The method was as thorough as it was speedy.

For bottom compaction one triple drum and two tandem hitched double drum sheepfoot rollers were used. These were powered by 50-h.p. crawler tractors. When the bottom 4 in was well packed, heavily loaded pneumatic rollers supplemented them to tighten the top 2 in. In the final stages, the pneumatics worked without the other units.

During the entire compaction period spike-tooth harrows followed the compaction units to maintain more uniform moisture content, to prevent any bridging effect of the rollers, and to eliminate surface compaction planes.



Improvised attachment on a tractor plow to remove partially mixed soil-cement mixture adjacent to forms.



Special built, wooden strike-off drawn by two tractors to level material between forms prior to soil-cement processing.

As usual, preliminary and final shaping was by means of motor graders. There were two types, one with four-wheeled drive, the other with tandem drive. After preliminary shaping, a trio of surveyors made careful check of the surface and marked any irregularities of elevation. These were corrected in the final shaping which then followed. It was planned that there should be a small amount of excess material to blade off to the edge and waste in the final finish—such excess being much preferable to a possible deficiency.

Mulching of the surface, before final rolling, was necessary to eliminate surface compaction planes due to the finishing operations. For this operation a device known as a weeder was used. This was attached to one of the farm tyre tractors. It was an assembly of three banks of long thin spring teeth, or "fingers" secured at intervals of $1\frac{1}{2}$ in to a frame 7 ft. in width. The depth of mulch could be regulated by hydraulic control on the weeder frame. This device was used during the later stages of pneumatic compaction as well as in forming the surface mulch. It took the place of nail drag and broom drag usually used in the mulching, was much more convenient to use, and gave excellent results on this particular soil.

All smooth rolling was by means of pneumatic equipment.

Smooth wheel rollers—two types—were tried out at first but, because of bad "pick-up" as well as excessive blustering, their use was abandoned.

The pneumatic rollers used were a special type made up of heavy discarded transport airplane tyres. They were pulled with smooth-tyred lightweight trucks. For the finish, the rollers carried no extra weight.

Protective Covering

For the protective covering, a fibre-reinforced waterproof paper was used.



A fleet of light pneumatic-tyre tractors used on mixed-in-place soil-cement construction.

This was furnished in sheets, each covering half the width of a 25-ft. lane, with allowance for lapping at the centre. For the purpose of retaining the moisture during the hardening of the soil-cement, the paper was a success, no added moisture being required. It also provided protection against light frosts.

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Processing extended from October 10 to November 20, inclusive—42 days. There were 35 actual processing days, including several days of light rain, averaging 11,338 sq. yds. per day, the maximum day's run being 25,668 sq. yds.

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Mixing train of rotary speed mixers during dry mixing operations.

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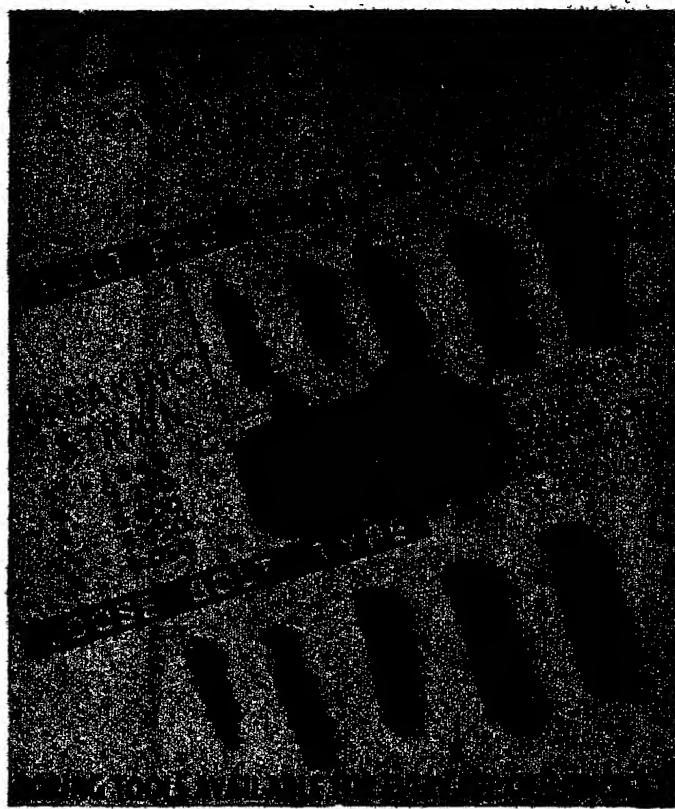
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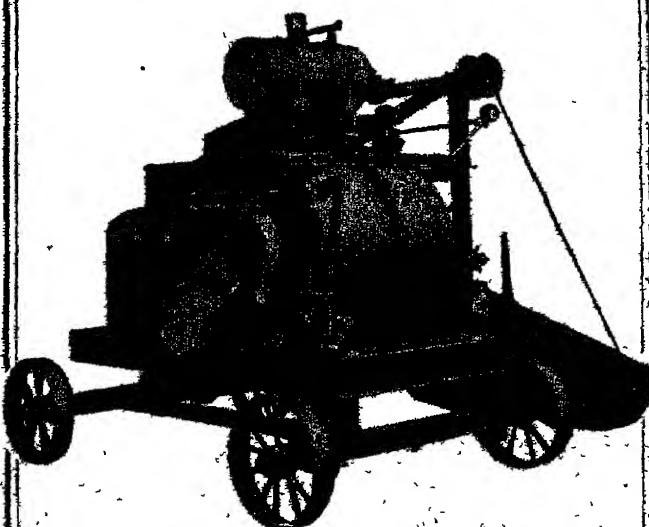
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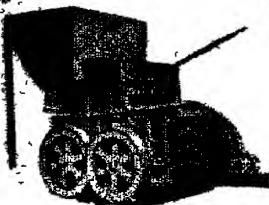
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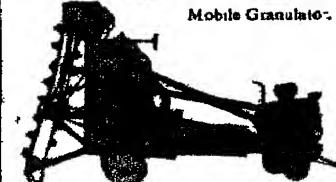


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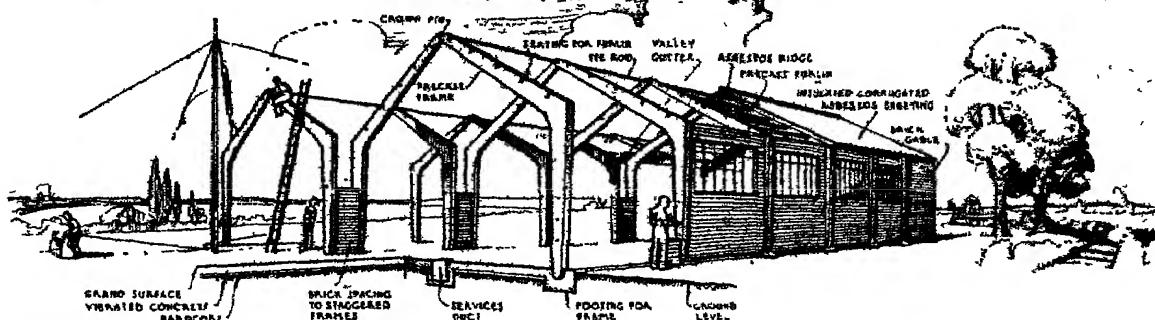
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BABAL	KAMALA
BASIRPUR	KALAKE
CAMBELLPUR	KALKA
CHAK JHUMRA	KALBAGH
CHAK AMBU	KALLUK KOT
CHAK KANBO	KAMOKE
CHAWAL	KANGANPUR
CHAWINDA	KANGRA
CHANANWALA	KAPURTHALA
CHANGAMANGA	KARTARPUR
CHENAB WEST	KAROR
RAK	KASAFLI
CHERHARTA	R. S. <i>Kahn</i>
CHIGWA WAENI	KHUSHAB
ROAD	KASUR
CHINJOT	KHANEWAL
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CHIARKANA	KOT KADHKISHEN
CHOTIANA	KANDAGHAT
DAHLHOUSE	KUNDIAH
R. S. <i>Parkes</i>	KHANNA
DAULATLALA	KHANPUR
DASKA	KHASA
DARUTA	KOT ADU
DERA BABA NANAK	KHARIKAN
DERA BAHAI KHAN	KILA BAIPUR
DERA HAWASABAH	KOHAT
DARBABARIH	KOT KAPURA
KARTARPUR	KOT LAKHPAT
DHARAMPUR	KURALI
DHARIWAL	LAHORE & LAHORE
DHILWAN	GANTT
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DINTANAGAR	LOHIAN KHAS
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DUNGA BUNGA	LYALLPUR
DUNYAPUR	MACLEOD GUNJ
EMWABAD	ROAD
FARIKOT	MAGHARWAL
FATHGARGH	MALISH
CHURIAN	MAJITHIA
FASILKA	MALAKWAL
FATEJANG	MALESKOTLA
FERGUSPUR CITY	MALKHU
& CANTT	MALOUD
GARHMANKAR	MALSIAN SHAKOT
GAHAR	MANDI BAHAUDDIN
GAIGHA	MANSA
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 BULTANPUR LODHI
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 Rawalpindi
 TALAGANG (R. S
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TAKHIA
THERI SANI
TESSIL SHAKAR-
GARI
THEBALKE
THAL

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AGRA
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ALIGARH
AMROHA
AMBALA CITY
AMELA CANTT
ATSAULI ROAD
BABHLA
BABHAN
BABARA
BARNALA
BASHPUR ROAD
BATH (R & B) BILASIPUR
BAHADURGARH
BAHJOI
BARETA
BASIKRATHEPUR
BAGAMABAAD
BHILWANI
BHUCHHU
BALLABGARH
BA RAUT
BUDHLADA
BULANDSHAHAR
BUNJOB
BEINDABAN
CHANDAUSI
CHANDPUR SIU
CHOLA
DADRI
DALMIA-BADRI
DIBAI
DEHLA DUN
DELHI
DEHLI SHANDELA
DEOGARH
DAMKAUR
DAURELA
DHAEMPUR
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ETMAUDPUR
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HATHRAS
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JARHAL
JALESBAR ROAD
JAWALAPUR
JIND CITY
JULANA
KAILANWALI
KANTH
KANDHLA
KAURARA
KHATAULI
KHEKRA
KHERIA

CAWNPORE
AHALGANJ
AKHEDALDA
AKHAILI
AKHILPUR
AKHLURA ROAD
AKHRAH
AKHUBYA
AKHUPUR
AKLANS

**TOBA TEK SINGH
VEHARI
VERKA
WAZIRPUR
WARBURTON
WASAWEWALA**

1 AREA:-

KARNAL
KAITHAL
KASHIPUR
KASIMPUR KHERA
KOSH KALAN
KOTDWALA
KURUKSHETRA
LEHGRAGA
LHAKSARA
LOHAR
MANDE BHAUR
MADLAUDA
MANJEPUR
MREROT
MILAK
MORADABAD
MUNDLANA
MURADNAGAR
MURSAN
MUTTRA
MUZAFFARNAGAR
NAJIBABAD
NAGARIA SADAT
NAGINA
NABHA
NANAUTA
NARELA
NARWANA
PALWAL
PANIPAT
PATIALA
PILKHUWA
RAIWALA
RAJ-KA-SAHS-
PUR
RAJGHTH-NARODA
RAJPURA
RAJMAN
RAMKAGAR
KAMPUR
BAMPUR MANRYA
KAN
RAMPURA PHUL
RAYA
REWARI
ROHTAK
ROORKEE
RIKHIKESH
SAFIDON
SAHAKANPUR
SAMPIA
SANGRUR
SARAI
SUNAM
SAMALKHA
SAMBAL HATIM
SARAI
SAKESAWA
SEOBHARA
SHIKOHABAD
SHAHABAD MAR-
KANDA
SHAMILI
SIRSIA
SONGPAT
SIMCHAOLI
TAPA
TAPETI
THANA BHAWAN
THANSAR
TUNDLA
TOHARA
TOHAMA
UKLAMA

AREA 2:-

ALLAHABAD
AMBEDKAR
AMOUBI
AMRIAT
ANGUPGANJ
AGRA
BHATI PUR
BEGUMA
BUKHTIYA

NEW DELHI AREA

AGRA	KARNAL	BALAMAU
ALA L	KATHAL	BALLIA
ALIGARH	KASHIPUR	BALKAMPUR
AMBROHA	KASHIMPUR KHERI	BANJANA
AMBALA CITY	KOSH KALAN	BANSASSA
AMBALA CANTT	KOTDWARA	BANDA
ATTAULI ROAD	KURUKSHETRA	BANGAR MAU
BABHALA	LEHAGAGA	BABA BANKE
BABIAN	LHAKSAR	BARELLY
BABRA	LOHABU	BARRAJ BAZAR
BARNALA	MANDI DHANAUHA	BARRONI
BASHPAT ROAD	MADLAUDA	BARAHALGANJ
BAH (B 8 Melangari)	MANGUPEUP	BASAI
BAHADURGARH	MREET	BASBARATGANJ
BAHJOI	MILAK	BASTI
BARETA	MORADABAD	BELLARIAN
BASIKIRATHPUR	MUNDLANA	BELTHARA ROAD
BAJAMABAD	MURADNAGAR	BENAKRES CANTT.
BHUVANI	MURSAN	BENAKRES CITY
BHUCHCHU	MUTTERA	BEWAR
BILABGARH	MUZZAFARNAGAR	BHDONI
BAKAUT	NAJIBABAD	BHARTHANA
BUDHLADA	NAGARIA SADAT	BHATTAKRANI
BULANDSHAHAR	NAGINA	BHATTMI
BINJOB	NABHA	BHITAURA
BRINDABAN	NANAUTA	BRITI
CHANDAUSI	NARELA	BROGAON
CHANDPUR SLAU	NARWANA	BILAUZIA
CHOLA	PALWAL	BILGRAM
DADEI	PANIPAT	BILPUR
DALMIA-BADRI	PATIALA	BINDHI ROAD
DIBAI	PILKHUWA	BIRBALPUR
DEHRA DUN	RAIWALA	BISWAN
DELHI	RAJA KA SAHAS-	BODARWAR
DELHI GHANDERA	PUR	BRIDGMANGANJ
DEOBAND	RAJGHAT-NARORA	BUDAUN
DAKAUR	RAJPURA	BURHWAL
DAUREALA	RAMAN	CAMPINGANJ
DHAMPUK	RAMMAGAR	CAPTAINGANJ
DHANARI	KAMPUR	CROWNPORE
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ETMAUDPUR	KAN	MANJEWAR
FARIDABAD	RAMPURA PHUL	CHANDWAK
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GHARAUINDA	SAPIDON	CHILWARI
GOT	SAHARANPUR	CHIRGAON
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GURGAON	SANGRUR	CHOWKACHAT
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HAPUR	SARAI	DATIA
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JAGDHRI	KANDA	DOKHIGHAT
JAHAL	SHAMLI	DULHARUPUR
JALESBAR ROAD	SIRSIA	DUH
JAWALAPUR	SOK SPAT	DUWAH
JIND CITY	SIMBHAPOLI	FAISALABAD
JULANA	TAPA	FATEHGARH
KALANWALI	TAPI	FATEHFUR
KANTH	THANA BHAWAN	FIYABAD
KANDHLA	THANSAR	GAHAR
KAURARA	TUNDLA	GARIBNAGAR
KHATALLI	TOHANA	GARURGANJ
KHEKRA	UCHHAMA	GRACIUS
KHERIA	UKLANA	GHOSI

CAWNPORE AREA I-

ACHALGANJ	ALLAHABAD	GOURKALGANJ
AGRAHADA	AMETHI	GURBAGAON
AGRAULI	AMOUBI	HARDWAH
AHMADPUR	AMRIKI	HANDBI KHAN
AKHRAVRA ROAD	ANGUPANI	HARIBHAI
AKTAFEN	AGCHA	HARRISON
AKSHYATHA	AKLIPUR	HAKKANBANDH
AKKARPUR	AKRIBELA	HARIPUR
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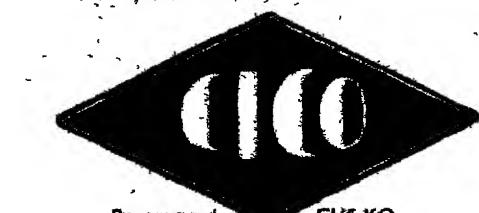
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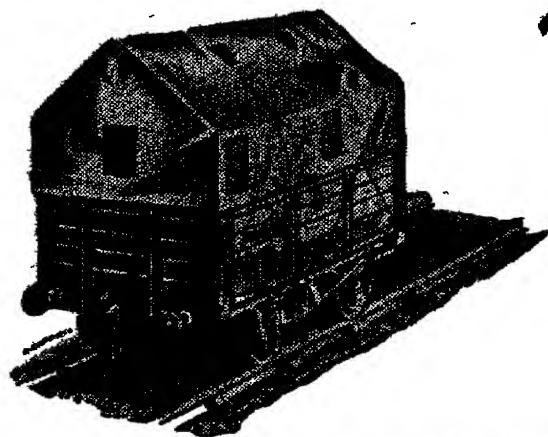
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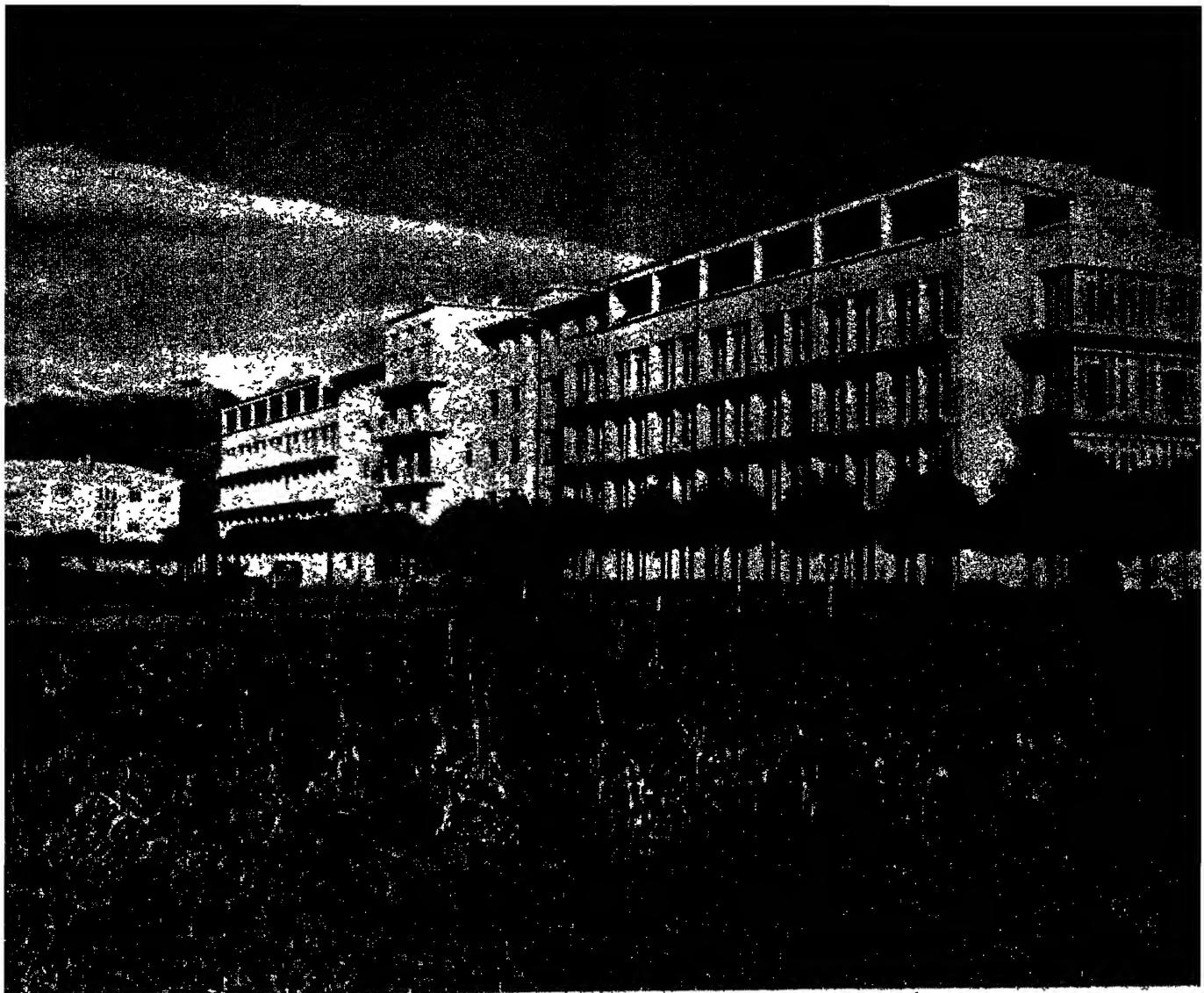
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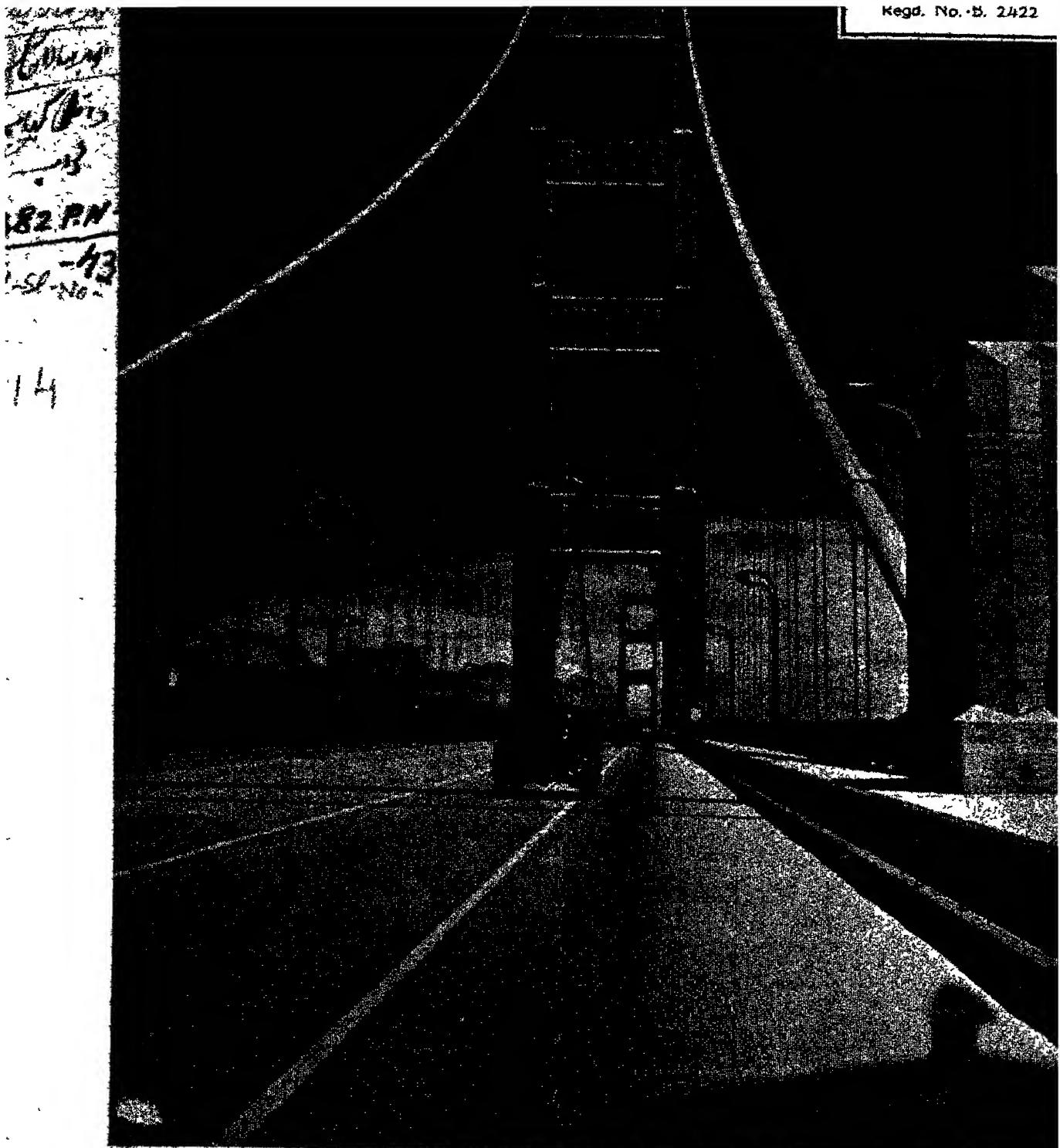


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THE GOLDEN GATE BRIDGE, CALIFORNIA (See Back Cover.)



INDIAN CONCRETE JOURNAL

VOLUME XIX

JUNE 1945

NUMBER 7

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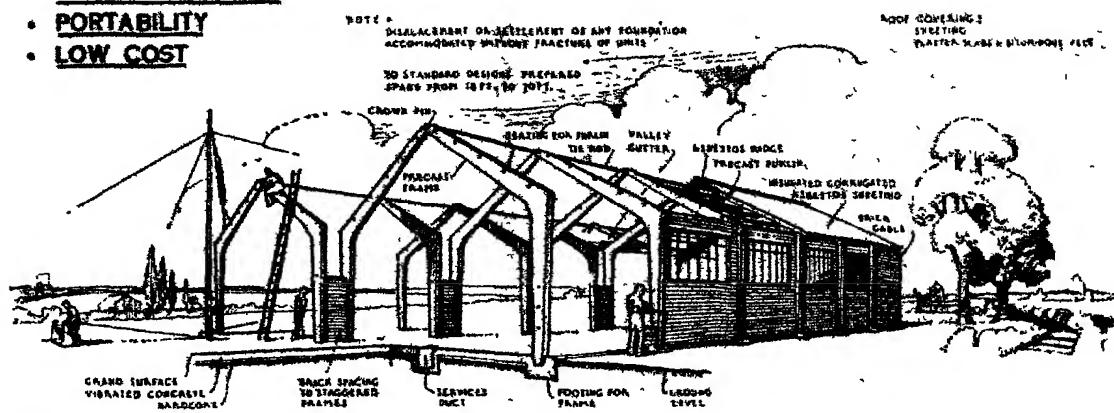
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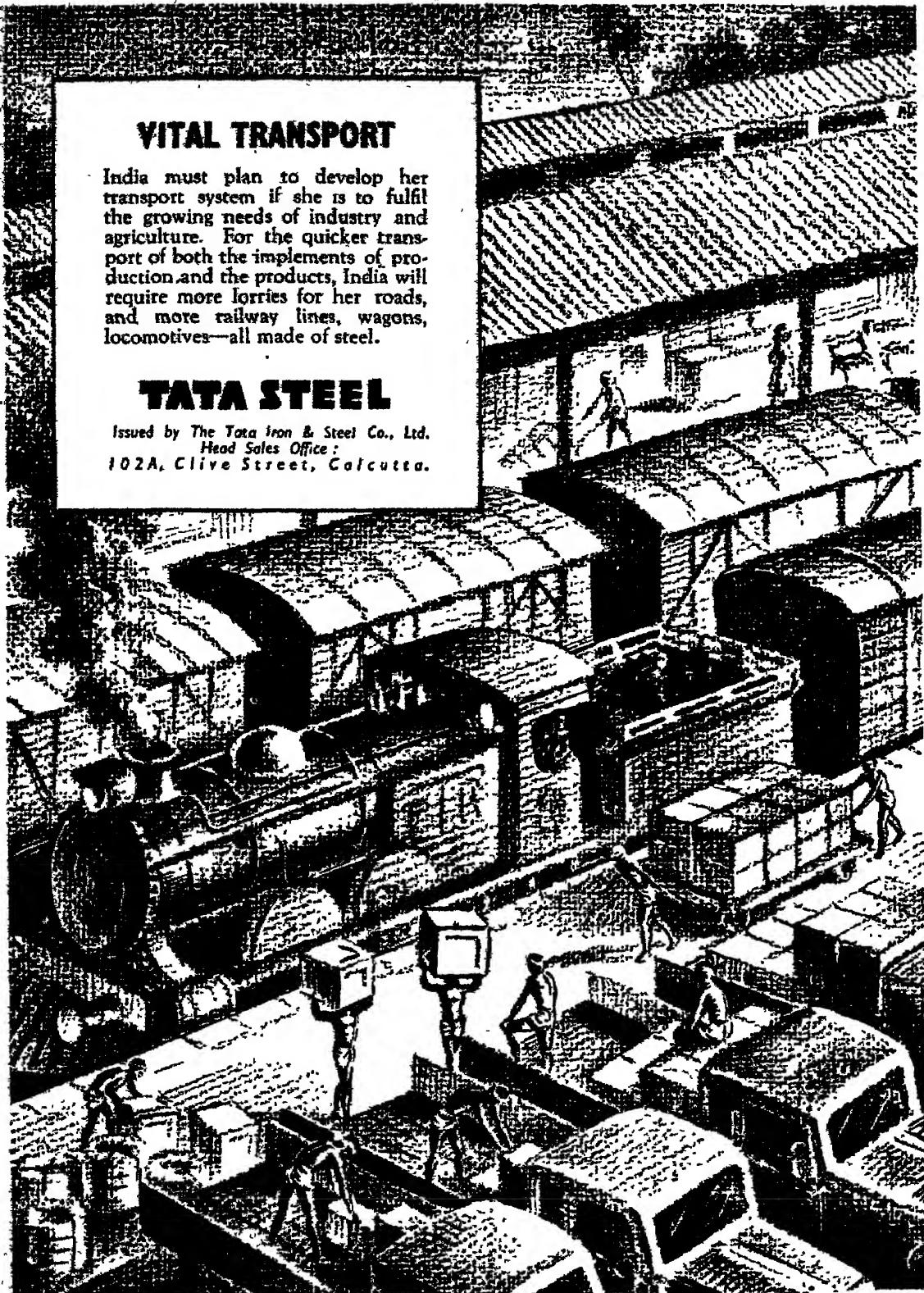
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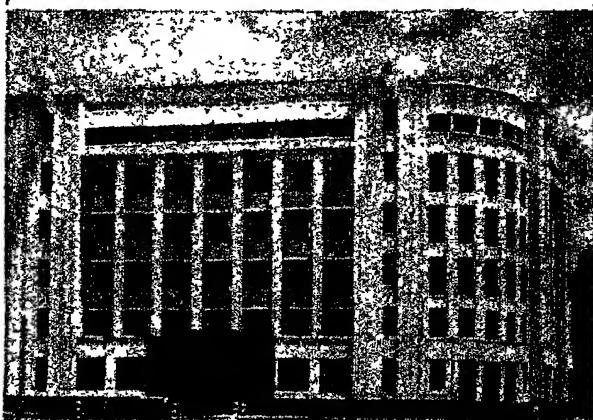
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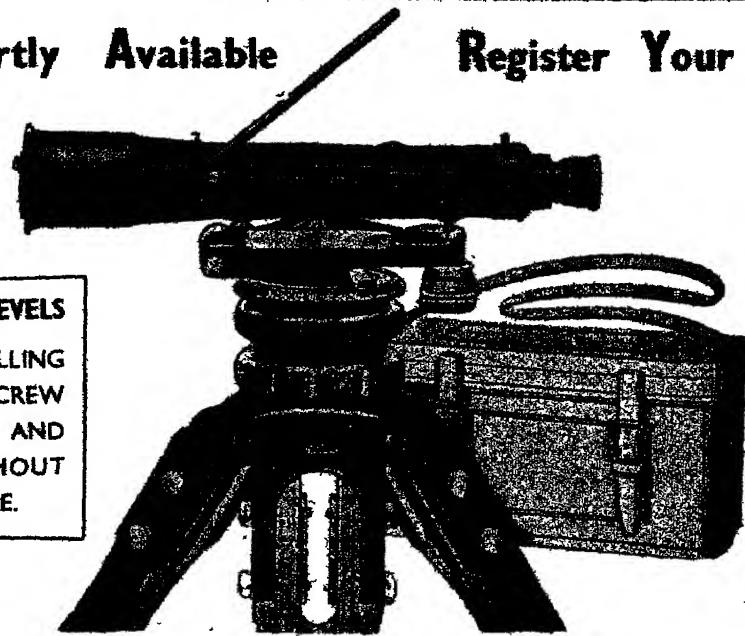
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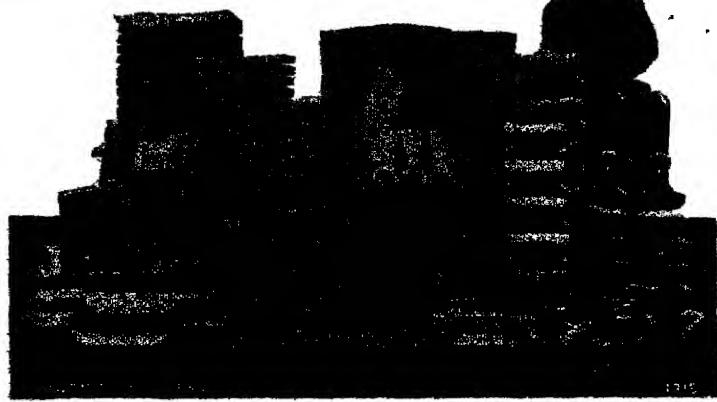
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EDITORIAL

THE RETURNING INDIAN SOLDIER



The average Indian soldier and villager will, according to Brigadier F. L. Brayne, one of the foremost champions of the cause of the demobilised man, demand four freedoms. *Firstly*, freedom from hunger, want, debt, and general insecurity; *secondly*, freedom from disease and suffering; *thirdly*, freedom from ignorance and boredom; *fourthly*, freedom from the exactions and tyranny of petty officials.

BEFORE large scale economic planning can take shape, it is obviously necessary that these four freedoms must in some way be realized. Nobody wants a return of the difficult days succeeding the last war. But these difficult days will assuredly return unless urgent steps are taken to meet and avert them.

Everyone interested in this important subject should read the book entitled 'Better Villages' by Brigadier Brayne, which gives a comprehensive account of all the important aspects of village life and well-informed suggestions for its improvement. We purposely say "well-informed" as the Brigadier has given the best part of his life to the study of Indian villages in the Punjab, and has made a remarkable improvement in those that he has tackled. But there are many difficulties ahead. One of them is the comparative lack of education at present imparted to the women of India. He maintains that one of the greatest problems of boys' elementary education is the way in which, after leaving school, they forget all they have learnt. If their mothers could interest themselves in their sons' studies this would not occur. No one has yet heard of the sons of literate mothers lapsing into illiteracy. He goes on to say that "every year scores of young men are trained for rural work of various kinds, and as one watches them at work before they leave their training institution one is struck by their smartness and their splendid promise. They are full of zeal and knowledge and determined to put things right whenever they find them wrong. A few years later, one comes across them again at work and one is unable to recognize them for the same people. They have stepped back into old ways and are content to pass their time in a dull routine imitation of what they learnt at their training school. I feel certain that one great cause of this disastrous change is that no man can live permanently ahead of his home. Whatever he has learnt or whatever progress he has made, he must, in the end, come back to the standard of his home, and the standard of his home is that of his wife. No soldier can fight in front and behind him at the same time, and the trained worker cannot hope to uplift his home as well as his neighbourhood to the standards he has so recently acquired. Unless he can gather inspiration from his home for his daily struggle, sooner or later he is bound to slip back to the old level."

The Concrete Association of India is trying to help in a small way by educating the returning soldier in the elements of concrete work, and in using cement in the correct manner. It would be a hopeless task to educate the tens of thousands of returning soldiers who need instruction in this matter. So the Association has set itself a goal of the formation of six or seven centres, each training a batch of some twenty men every six months. These men will have to be picked as potential instructors themselves, so that elementary knowledge of cement and concrete work can be disseminated throughout the country. While we cannot aspire to educate many Indian women in the

technicalities of cement work, we hope to interest them in the need for better and cleaner houses. Cement is the recognized material with which labour saving homes can be built. There is nothing so easy to keep clean as a concrete slab. Flies which breed mainly in dirt, can only be dealt with partially by disinfectants. If filth and refuse are allowed to lie about, all the disinfectants in the world are powerless. Flies and insects of all kinds, including malarial, bring disease and death, and must be eradicated before healthy living conditions are established. Just as cement concrete has been used in war as a means of fighting the enemy, so it has to be used in the years to come to fight the more lasting and powerful enemies of dirt and disease.

It is often said that a poor villager cannot afford to use cement, actually he cannot afford to do without it. As a first step a small amount of cement can be used to bring a very great amount of improvement in such things as the construction of clean floors, soak pits, open drains, latrines, ventilators, trackways, etc.

Brigadier Brayne says that "It is easier to establish domestic reforms which the women understand and appreciate (such as the paving of streets or the improvement of wells), even though they cost more money and bring in no cash return, than to spread the use of good ploughs or to persuade the people to buy good bulls."

At the end of his excellent book he gives pointers to a short term post-war plan. He says "there is bound to be a gap between the end of the war and the time when large-scale planning begins to benefit the common man. This gap must be filled by a general uplift drive—better seeds, consolidation of holdings, manure pits, anti-erosion work, co-operative enterprise, cottage industries, ventilators, chimneys, improved wells, the growing of protective foods, domestic training and welfare work for women, youth movements, organized recreation—all the little things which cost so little but mean so much in improved health, wealth and wellbeing. This programme will serve to keep everyone happily and profitably busy till the big plans mature and will do more than anything else to keep the people together, to prevent the reaction and disillusionment that is so likely to follow the relaxation from the strain and effort of war, to prevent the ex-soldiers drifting apart, frittering away their savings, and forgetting their comradeship, loyalty and discipline, and it will convince everyone of the good-will of Government and of course its desire and capacity to win the peace as well as the war."

Here are some of the nation building works which the book suggests can be started at once by returning soldiers.

I. Land.

- (a) Anti-erosion, soil conservation and reclamation, tree-planting, re-afforestation, control of

grazing grounds, terracing and embanking or bunding of all unlevel arable land, subsidies for all self-helping schemes of closure, reclamation and conservation. India is drying up and erosion is its biggest single cause of poverty. Until erosion is tackled the soil and water of India are wasting assets and every scheme of land development is increasingly costly to execute and maintain and gives less and less return.

(b) Consolidation of fragmented agricultural holdings; this will increase crop production by at least 25 per cent., realizing a sum greater than the whole land revenue now paid in areas where it is required.

II. Water and Power.

(a) Canals, barrages, storage dams, hydro-electricity, tube-wells, should be made wherever possible

(b) Improvement of water supply in existing wells, repairing wells and sinking them should be taken in hand wherever possible. Well irrigation is the greatest insurance against famine and therefore it should pay the lowest possible taxation.

(c) Bund building should be done wherever desirable and possible

(d) Water lifts and pumps of all kinds must be encouraged

III. Farming.

(a) There must be complete replacement of inferior seed by good seed.

(b) All the sidelines of farming should be developed, such as stock breeding, dairying, fruit, poultry, bees, silk, lac, sheep, wool, mohair, etc.

(c) Agricultural and other rural services should be fully financed and organized so that the farthest farm and village will be served. (Concrete trackways and even cycle-tracks will very greatly help in allowing free communication in all weathers especially in the wet parts of India—Ed.).

(d) The anti-social and wasteful crime of cattle stealing must be seriously tackled. Consolidation of holdings will make hedges and fences possible, and tattooing and registration of livestock will be developed.

(e) There must be price control of principal agricultural products to ensure a fair return to the producer

(f) The farmer will be encouraged to put his heart into his work by :—

- (i) Consolidation of fragmented holdings.
- (ii) Better rural services of health, sanitation and medical aid (including maternity aid and drinking water), education (including domestic training for women), radio, recreation, culture, etc.
- (iii) Controlled prices for his produce—a fair price is better than good seed!
- (iv) Fairer distribution of taxation. The small farmer carries more than his share of the burden and the privileged classes, whether capitalist or agricultural, urban or rural, carry too little.
- (v) Credit and marketing facilities and rural savings systems
- (vi) Developing communications roads, railways, ports, air services, posts, telegraphs, telephones, radio. Subsidizing self-helping improvement of village roads. Forcing able-bodied men by law to give (as in Turkey) twelve days' work (or pay for a substitute) to village roads and other community work (building tree planting, etc.) Introduction of rubber tires for all bullock carts! (It may be possible to use old motor tires cut into strips or gaiters to protect roads from the destructive influence of the steel tires of bullock carts. This Association is at present engaged in experimental work on these lines—Ed.).

Other Essentials :—

IV. Industry—Maximum possible development.

V. Health Improvement.

VI. Women's Welfare.

VII. Suppression of Bribery.

VIII. Education.

Complete reorganization of education to suit the actual needs and realities of town and village and the social and economic states of the people.

In a short editorial it is impossible to do justice to so vast a subject. But as the proper use of cement and concrete must play a vital part in village uplift, we think that a study of the problems affecting village life, is well worth consideration by concrete engineers

DETAILS OF CAPTAIN COOK GRAVING DOCK, SYDNEY

By

MAURICE W. MENAFFEY, B.E., A.M. Inst. C.E., Chief of the Dock Construction Section, Australian Department of the Interior.

The Public Relations Officer, of the Office of the High Commissioner for Australia in India, has very kindly put at the disposal of the readers of this Journal the following article of the Captain Cook Graving Dock, which has just been completed in Sydney harbour.

This is one of Australia's greatest single engineering achievements. This dock can accommodate any ship afloat with an appreciable margin. Sir Alexander Gibb and Partners were commissioned to examine and report on the site, and assisted in the supervision of the construction work. Sound rock was available for foundations at a reasonable depth.—(ED.)

General Layout.

An area of some 30 acres has been reclaimed to provide wharves, workshops and services.

The dock runs roughly north by west, with entrance facing north, approximately halfway between Potts Point and Garden Island. From the entrance, the walls are returned at right angles to the centre line, to meet a wharf on each side, running north approximately parallel to the dock.

The east wharf, 259 feet east of the dock centreline, is a reinforced concrete counterfort wall structure, backfilled, 360 feet long. This may be later extended to link up with the cruiser wharf at Garden Island.

The west wharf, approximately 149 feet west of the dock centreline, is a reinforced concrete pile and deck structure, which runs north for 486 feet to connect to the roundhead of the fitting out wharf.

These two wharves form an entrance basin 400 feet wide.

The fitting out wharf, of heavy reinforced concrete construction, lies to the west of the dock, running north-east by north, on the prolongation of the line of the existing wharves on the east side of Woolloomooloo Bay, for a distance of 860 feet.

The dock is served by two electric travelling cranes, each of 50 tons capacity at 110 feet radius, one on each side of the dock. The dockyard area generally is served by two diesel locomotive cranes of 5 tons capacity travelling on $3\frac{1}{2}$ miles of 4 ft 8 $\frac{1}{2}$ in gauge railway track, with two mobile cranes of similar capacity.

The fitting out wharf carries a 40 ton electric travelling and a fixed crane of 250 tons capacity at 118 ft radius.

The main workshops are located on reclamation to the east of the dock, and two smaller workshops behind the fitting out wharf.

Graving Dock.

The dock is constructed in mass concrete founded throughout on rock, and was built in the dry inside a cofferdam. It measures 1,177 feet from the cope at the entrance to the cope at the head of the dock, with a width at entrance of 147 ft 7 $\frac{1}{2}$ in and a depth over the sill of 40 ft 6 in below datum, which is approximately L W O S T. The level of the dock cope and the reclaimed area generally is 10 feet above datum.

The area between the walls and the banks of the cofferdam has been reclaimed by backfilling.

The dock walls are of gravity section, generally 41 ft 6 in wide at the base, stepped in to 13 ft. 7 in at the top. Four continuous altars are provided at inter-

vals up the wall, in addition to a bilge altar and steps at the base.

Within the walls, two subways run right round the dock. The upper carries fire, fresh water and compressed air mains, and cables for operation of valves and for supply of electrical services. Branches are taken up through the walls at intervals to service connections at the cope and to installations in the dockyard.

The lower subway carries a 21 inch dia salt water main for supply to ships in dock. Branches are taken through the walls to outlets just above bilge altar level, from which special flexible bronze hoses are provided for connection to the ship.

Direct access to these subways from the surface is provided by three shafts on each side of the dock, which are fitted with armour plate covers.

A cross subway passes under the floor of the dock below the entrance sill, connecting the subways on each side and providing a route for electric cables and service mains.

Three grooves, formed in granite blocks, have been provided in the dock for the floating caisson gates, an outer, or emergency groove, and an inner, or main groove, at the entrance and an intermediate groove about one-third of the length from the entrance.

The clear length available with a caisson in the emergency groove is 1,134 feet.

The intermediate groove enables the dock to be divided into two sections, the inner one of 700 feet, and the outer of 395 feet clear lengths. The arrangement of valves for filling and emptying is such that each section can be used independ-



Concrete being poured in the construction of Sydney's new ten million pound graving dock which can accommodate any ship in the world. The concrete for the body of the dock was poured in 40 ft. lengths, gaps of five feet being left between the lengths. Concrete was poured in the gaps from two to three months later and so after most of the shrinkage of the 40 ft. blocks had taken place. The completed walls have shown no signs of faults or cracks.

ently of the other. All grooves have inner and outer faces so that water may, if necessary, be impounded within the dock to a level above tide level.

The floor has a level strip 20 feet wide along the centre, and slopes each side from this to the dock drainage channels, at a fall of 6 in. in 49 ft 6 in.

At the entrance, a sill is formed 4 ft. 6 in. above floor level to carry the main and emergency caisson grooves. This sill is level with a drain on the inner edge to carry any leakage water to the side drains. Another sill, raised 1 ft. 6 in. above the floor, carries the intermediate caisson groove.

The filling of the dock is carried out by means of two filling culverts, one on each side of the dock. These lead from the return walls down behind the dock walls proper for some distance and then connect up with culverts formed in the base of the walls.

Each culvert discharges into the dock through two sumps in the edge of the floor, one just inside the main entrance sill and one behind the intermediate sill.

The same sumps and the portions of culverts in the walls are used for dewatering. As, however, the pumping equipment is all located on the eastern side of the dock, the sumps on the western side of the floor, are connected to those on the eastern side by means of 4 ft diameter culverts cast in the floor.

The two floating caissons were designed by Messrs Vickers Armstrong, of Barrow-in-Furness. They are 151 feet long by 37 feet wide and 32 feet deep, with a displacement of 3,655 tons at light draft of 33 ft 6 in. They are of all-welded steel construction, bolts or rivets being used only for attachment of armour plating. The sides are protected above water level with 1½ inch armour plate and a 4 inch armour plate deck is provided. The top deck is finished off with wood-block paving.

The stem and stern are built with a slope of eight to one, as are the grooves in the walls, so, that when floating light, a caisson has adequate clearance for handling into the grooves. When sunk in place, there is about 10 inches clearance at each end, and tapered timber blocks are used to ensure accurate centering.

Each caisson has a 16 ft diameter cylindrical water ballast tank running fore and aft, divided into 3 compartments to adjust trim, and tidal chambers on each side above normal water level, separated by a longitudinal bulkhead. When the caisson is sunk, water is first admitted to the ballast tanks. This brings the inlets to the tidal chambers below external water level, the inlet valves are opened and the chambers flooded. The caisson then continues to sink until the tidal chamber valves are closed.

When raising the caisson, the water in the ballast tanks is blown out by compressed air, while the tidal chamber valves are left open to allow the water out.

Pumphouse.

All the pumping equipment for the dock, except the small subway drainage pump previously mentioned, is concen-

trated in an underground pump house located in the angle formed by the east dock wall and the east return wall. This pumphouse is a reinforced concrete structure 140 feet long by 40 feet wide, built mostly in rock excavation, with special protection against bombing.

The main pumps are three in number, of the horizontal spindle centrifugal type, with 36 inch dia. suction and 34 inch dia. delivery driven at 722 r.p.m. by synchronous motors of 3,000 KVA operating on 5,000 volts.

The pumps draw from the main suction chambers located below the pumphouse floor and discharge by way of reinforced concrete culverts through 6 feet dia. gate valves in the east return wall. In addition, to a main discharge valve in the wall, each pump has a special automatic rapid-closing valve on the discharge side to avoid excessive speed in reverse of the pump and motor when shut off, as the pumps are some 40 feet below low water level. Another automatic self-closing valve is fitted to the suction side of each pump.

To impound water in the dock above tide level, the delivery of one main pump can be by-passed into the east filling culverts, water being supplied to the main suction chamber through a special 6 ft. dia. valve and culvert in the east return wall.

The three pumps are capable of dewatering the dock in 4 hours at a rate of over 4,500,000 g.p.h per pump.

Special pumps are provided to deal with all dock drainage and seepage water. Also in the pumphouse are two fire pumps capable of delivering 1,825 g.p.m. against a head of 270 ft. to the fire mains round the dock, and three circulating pumps supplying the 2½ inch dia salt water main in the lower subway.

The main culvert valves, 4 of which are of 9 feet dia., and 9 of 6 feet dia., are of the double faced wedge type and are operated by electric motor through worm and wheel gearing. There is also emergency hand operating gear.

All pumps and main valves are operated by remote control from a control desk in the operating floor of the pumphouse, and the system is electrically interlocked to ensure correct sequence of operations. Visual indication of operations is given by lights on a mimic diagram in front of the control panel.

Dock Cranes.

The two electric travelling cranes, one on each side of the dock, are capable of lifting 50 tons at a maximum radius of 110 feet up to a height of 110 feet above low water. An auxiliary hoist is also provided to lift 15 tons at 120 feet radius. Their speed of travel with a 50-ton load is 60 feet per minute.

The cranes run on double 111 lb. per yard rails at 30 feet centres, the front rails being carried on the top of the dock walls and the back rails on a 4 ft. deep reinforced concrete beam supported on 18 inch x 18 inch reinforced concrete piles driven to rock at 6 ft. 8 inch centre. The crane beam is laterally braced by tie beams to the back of the wall every 20 feet.

As these cranes straddle the 4 ft. 8½ in. gauge railway tracks, along the dock

side, the towers have been designed to give clearance for the passage underneath of rail traffic, including the two 5 ton diesel locomotive cranes.

To facilitate the handling of ships and the caissons there are 12 electric capstans of the constant current type, each capable of exerting a pull of 20 tons at speeds of from 50 to 100 feet per minute.

Floating Out Wharf.

The fitting out wharf is of reinforced concrete construction, consisting of two rows of piers spaced 100 feet apart transversely and 50 feet longitudinally.

The piers are 15 feet diameter at the base, founded on 12 timber piles driven to rock. About 12 to 16 feet above the base, the diameter is reduced, and the piers brought up to near low water level as hollow columns of 7 ft. 6 inch external and 3 ft 6 inch internal diameter, the hollow cores being filled with sand. The piers are terminated in solid heads of rectangular sections, which in the case of those in the rear, have vertical slots to take the ends of precast beams for retaining the back fill behind the wharf.

A heavily reinforced haunched portal beam, 7 ft 7½ inch deep provides the necessary transverse bracing between the front and rear piers, doing away with any diagonal or underwater bracing.

A 16 inch thick reinforced concrete deck, surfaced with tar-macadam, is carried on longitudinal beams at the front, centre and rear.

Expansion joints with bronze and stainless steel sliding plates are provided at approximately 300 feet intervals.

In order to provide all possible space for railway tracks and workshops, the area behind the wharf is reclaimed with selected backfill retained by a rubble bank built up below the wharf to a level of 9 feet below datum. Above that level, a retaining wall is formed of precast concrete beams spanning between the piers, and the rear longitudinal beams.

An electric travelling crane of similar type to the 50-ton dockside cranes, capable of lifting 40 tons at 90 feet radius to a height of 152 feet above low water, is carried on the wharf. The pin of the jib is 99 feet above low water, the unusual height of the crane being necessary to permit effective use when an aircraft carrier is alongside.

Exceptionally heavy lifts will be handled by a fixed cantilever crane. This has a capacity of 12½ tons at 165 ft radius and 250 tons at 118 ft. radius, at a height of 160 feet above low water. It is carried on four reinforced concrete cylinders 15 feet in dia., sunk to rock, which in this locality is about 100 to 110 feet below datum.

The piers are spaced at 50 feet centres each way, and are tied together above low water by heavy reinforced concrete beams carrying a concrete deck. The crane foundation structure forms part of the fitting out wharf.

Power House.

During normal operation, electric power for the area will be drawn from the Sydney County Council's supply, via two 33,000 to 5,000 volt substations, each of 5,000 K.V.A. capacity, but for emergency operation, an independent powerhouse

has been provided. This is a reinforced concrete structure, built mainly in rock excavation in a lift face at the south-west corner of the area and covered to give protection against aerial attack.

In addition to the stand-by electrical equipment, which consists of three 1,250 K.V.A. diesel-driven alternators generating at 5,000 volts, the powerhouse also contains the installation for supply of compressed air to the dockyard, comprising two compressors of 1,200 cu. ft per minute, and one of 500 cu. ft. per minute of free air, a 500 K.W. motor-generator set for ships' supply and a 160 K.W. Austin constant current motor generator for capstan operation.

Workshops.

The main workshops, 450 feet long by 140 feet wide, are of steel frame construction with reinforced concrete blast walls faced with brick. The three rows of main columns are carried on 18 inch \times 18 inch reinforced concrete piles driven through the reclaimed ground to a depth of 15 to 20 feet into the old sea bed, and the concrete machine bases are on timber piles similarly driven.

Each of the two bays carries two overhead travelling cranes, one of 10 tons and one of 60 tons capacity.

Construction of Cofferdam.

Although a number of bores had been put down over the area during the investigation of proposed sites, it was necessary to make a much more exhaustive survey of the foundation conditions.

More than 200 pipe and wash bores were put down along the proposed line of the cofferdam embankments and over the area generally and from their results a rock contour plan was prepared. In addition 22 three inch cores were taken with a diamond drill plant to prove the quality of the rock, particularly over the area proposed for the dock structure.

Other preliminary work involved the re-location of water, telephone and electric power mains to Garden Island, which at that time were all laid on the sea bed across the site.

As the area of land available at Potts Point foreshore was very limited, it was first necessary to reclaim about 3½ acres to provide a working area.

Construction of the cofferdam was commenced at the beginning of 1941. This was made up of two embankments, the north west running from the end of Potts Point and curving round eastwards to meet Garden Island, and the south-east, starting from Potts Point, about 700 feet further south and curving round to north to meet the southern tip of the island. These consisted essentially of sandstone ballast banks retaining a clay core in the centre of which a steel sheet piling wall was driven, and enclosed an area of approximately 33 acres.

The first stage of construction consisted of placing the ballast toe banks, about 70 ft. each side of the cofferdam centreline, by hopper barges, located in position from temporary timber piles previously driven by a floating pile frame. Clay hearting was then dumped between the ballast banks by the same means to a level about 7 ft. below the crest of the banks. The second stage ballast was

then placed partly on the lower banks and partly on the clay to bring the outer face of the bank up at the required slope and provide no less than 10 feet cover over the clay. By taking advantage of the tides, it was possible to use hopper barges to bring the ballast up to 3 feet below low water, above which hand dumping from shallow draft flat-top punts was adopted, to about half tide level.

The second stage clay hearting, together with the final ballast capping at the sides and top of the banks, was tipped by lorry from a temporary timber staging built to carry the pile frames for driving the sheet piling. As the banks approached final level, the superstructure of the staging was removed, the piles being left in.

The construction of this staging and the pile driving followed as closely as was possible on the first stage of bank construction. Four frames were used, two on each section of the staging of which one had to be specially built to handle the 70 feet lengths of piling required over a portion of the south-east embankment.

Except for a few hundred feet of second-hand U.S.A. Luckwanna piling used at the beginning, the sheet piling was of a modified Larssen section, weighing 50 pounds per linear foot. As the maximum length obtainable was 60 feet, all piles over that length had to be spliced.

Splices were made with a $\frac{1}{2}$ " thick fishplate each side of the web, secured by six $\frac{1}{2}$ " dia bolts in each section of pile. The bolt holes in the pile were slotted by means of an oxyacetylene torch and the nuts spot-welded after tightening. In addition to the fish-plate, the flanges were butt-welded to provide against stresses in handling.

No trouble was experienced with the

splices during driving or subsequent extraction.

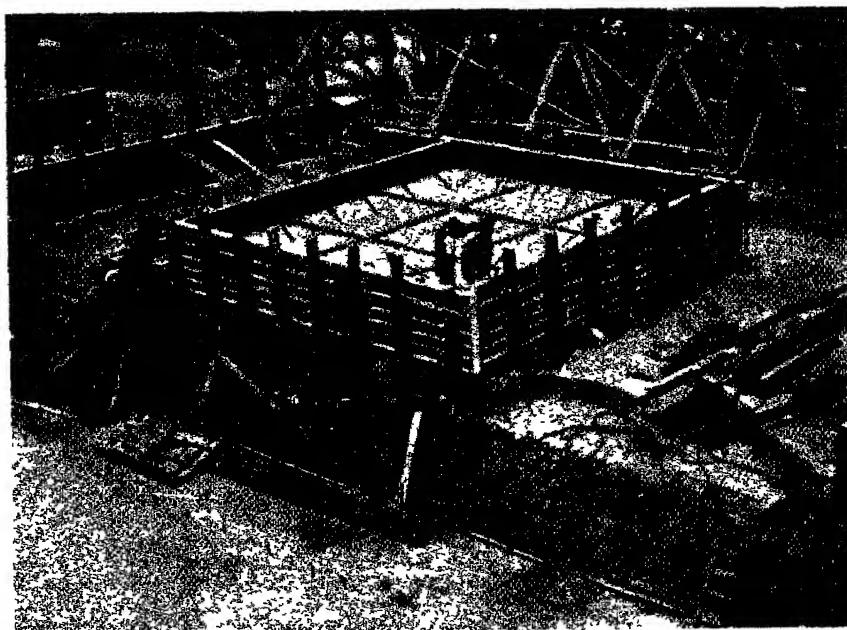
If possible, the piling was driven to rock, but where this was impracticable, because of the depth, the piles were driven into a bed of clay overlying the rock. A considerable length of the south-east embankment required the use of 70 ft. piles, the longest used, and called for hard driving through a stratum of compact sand.

McKernan Terry double-acting hammers operated by compressed air were used for driving, the heaviest being a No. 10B3.

For the closing of the cofferdam alternate piles over a wall length of 200 feet were cut through at a low water level, and the upper sections raised and wedged up to form a series of weirs. These provided sufficient waterway to prevent excessive velocity and scour through the gap in the piling as the last few piles were driven. An apron of ballast was placed in front of the openings to prevent scour of the clay hearting adjacent to the piling.

As the water inside the cofferdam approached its minimum level, as determined by the tide, the wedges were knocked out and the upper lengths driven down to close the gaps. Clay was then tipped alongside the piling to complete the seal, and the bank completed in the ordinary way.

Provision for the refilling of the dock was made by laying two 21 inch dia steel pipes through the western embankment with their centres at 2 feet below low water. Where the pipes passed through the sheet piling, the piles were cut short and driven to 4 feet below datum. Special pieces of piling with short lengths of pipe passing through and welded to



DOCK FLOOR—Pouring concrete on the floor of the new graving dock at Sydney. The floor of the dock was built as five rows of blocks each twenty-two feet square and varying in depth from five feet to twenty-five feet according to the rock foundation. The completion of the dock has made Sydney a naval base of the first rank as any ship in the world can now be refitted there.

them were then placed, and the remaining lengths of pipe connected with heavy rubber sleeves to provide flexible joints.

While the cofferdam was in course of construction, two dredges, one of the ladder bucket type and one duplex grab were employed to remove as much as possible of the soft material overlying the rock on the dock site. Some 170,000 cu. yds of sand and clay were removed in this way, before the closing of the cofferdam made it necessary for the dredges to leave the area.

Dewatering.

As soon as the cofferdam was completed, in February, 1942, dewatering was commenced by the use of pumps mounted on barges and discharging over the embankments through a flexible-jointed floating pipeline. Sumps had previously been dredged to provide for drainage of the areas as dewatering was completed.

The water level was lowered in 5 foot stages, every 5 days, the pumping generally occupying 2 to 2½ days, and the balance of the period being allowed for drainage and consolidation of the embankments.

A close check was kept on the movement of the embankments during dewatering and for a considerable time thereafter. An appreciable amount of lateral movement of the sheet piling was observed, particularly at the curve of the north-west embankment, where the maximum displacement eventually reached more than 2 feet. Some vertical settlement also took place but in no case were the movements serious enough to cause any trouble.

The cofferdam proved exceedingly effective, the greatest rate of leakage being some 20,000 gallons per hour for a length of wall over 4,000 feet.

Most of the inflow occurred through the original reclamation where the end of the western sheet piling wall met Potts Point foreshore. This was largely overcome by extending the sheet piling further inshore with short lengths.

Excavation.

As soon as the exposed sea bed was hard enough to carry plant an access road was constructed down from the foreshore on the western side and excavation begun. Caterpillar track, steam and diesel-powered shovels were used, as many as eleven being in operation at one time, ranging from $\frac{1}{2}$ cu. yd. to $2\frac{1}{2}$ cu. yd. capacity. Disposal was by means of motor trucks and all suitable material was placed on the inner sides of the cofferdam embankments to form part of the permanent backfilling.

The rock formation rose to form a ridge linking Potts Point and Garden Island, falling away generally to the north-east and south-west. On the ridge, the quality of rock proved so satisfactory that, in place of the 8 feet originally contemplated, a minimum depth of 5 feet of concrete for the floor was decided on, over the area from the main sill to the intermediate sill. South of this, however, the rock was not so good, and it was necessary to carry the excavation much deeper.

The greatest depth of excavation for the floor was about 70 feet below datum,

making the floor 25 feet thick at that point.

Towards the southern end of the dock, on the east side, a bed of shale was encountered, underlying sound sandstone. This was dealt with by sinking a cut-off trench around the edges of the foundation to a depth of about 85 feet below datum and filling with concrete. Apart from this cut-off trench, the maximum depth of wall foundations was approximately 75 feet below datum.

In this south-eastern area, the general level of wall foundations was so low that it was necessary to drive steel sheet piling behind the line of the wall to retain the toe of the backfilling. This was driven before excavation, and as the later proceeded, the piling was strutted back from the previously poured concrete floor units.

The total quantities of excavation carried out in the dry over the area of the dock and entrance basin amounted to some 120,000 cu. yds of rock and 260,000 cu. yds of other material.

To prevent, as far as possible, the passage of pressure water into the sandstone rock of the foundations, an extensive programme of grouting was carried out right round the perimeter of the excavation, holes being sunk about 20 feet into the rock at 10 feet intervals and grouted at a pressure of 40 pounds per sq in.

In addition, the rock below the cut-off walls across the dock entrance and under the caisson grooves was grouted to a depth of 25 feet at 60 lbs per sq inch.

Concrete.

The greater part of the concrete poured was supplied from a central mixing plant established on the foreshore of Potts Point opposite the southern end of the dock.

Aggregates were brought in to a high level street above the plant and distributed by belt conveyors to bins built on the cliff face below. From the bins, another system of conveyors delivered the aggregates to the batching bins at the top of the mixing plant, whence it passed the batching hoppers to three mixers of 2 cu. yds capacity each.

All batching was done by weight, cement, aggregates and water being weighed separately.

Bulk cement was used at the central plant being brought by barge to a temporary wharf at the southern end of the reclamation and thence delivered by two Puller-Kenyen cement pumps to a silo adjacent to the plant. Provision was also made for the use of bagged cement by an elevating conveyor to the silo.

An additional small plant with a single 1 cu. yd mixer was erected on the reclamation south of Garden Island to supply concrete for the east wharf and the pump house.

The general scheme for concreting the dock called for the central mixing plant to deliver concrete to the bottom of the excavation by 1 cu. yd skips lowered down a ramp behind the southern end of the dock. There they were hauled by narrow-gauge diesel locomotives to overhead trolley transporters which lifted and deposited them. The transporter ran on rails laid on the outer units of the

dock floor, which had previously been poured by the aid of mobile cranes.

The best day's output when this plant was in full operation was some 1,900 yards during three shifts.

The dock floor was concreted in blocks, generally 22 ft. 6 in. long by 20 ft. to 24 ft. 9 in. wide, poured alternately with an interval of 6 weeks between adjacent blocks, to minimise contraction cracking. Because the necessity for speed, however, it was not possible to adhere to this sequence, particularly with the outer blocks carrying the transporters. In such cases, provision was made for grouting the joints between units.

To prevent the development of any hydrostatic uplift beneath the floor, a system of half-round 6 inch dia. earthenware drains was laid on the rock foundation of each block before concreting. These were led to a central 4 inch dia. earthenware pipe riser, which was brought up as concreting progressed. A hole was drilled below each central riser to a depth of 70 feet below datum, and the pipes terminated at finished floor level, in a ball and socket hydrostatic relief valve. Similar drains were laid at intervals across the foundations of the wall units and brought up to relief valves at the edge of the floor.

The mass concrete of the floor was initially terminated at a level two feet below the finished level to provide a working surface during construction. It was finally finished off with a 1 ft. 8 in. thick layer of richer concrete topped with a 4 in. layer of granolithic surfacing placed as dry as possible, while the lower concrete was still green, in four panels per unit to reduce surface cracking.

The dock walls were built in units 40 ft long with five foot gaps between the 40 foot lengths, these gaps being concreted 8 to 12 weeks after the equivalent pour in adjacent blocks. This period allowed most of the initial shrinkage of the concrete in the 40 foot blocks to take place, while still allowing for some further shrinkage to provide for subsequent re-expansion.

The connections to the cope from pipe and cable services in the wall subways were largely concentrated in the five foot sections in order that the main wall units could be built up to cope level more quickly by eliminating the special form work required for the connections.

Provision was made against leakage at wall construction joints by forming a 6 inch dia hole across the joint. After the walls had been brought up to final level the holes were thoroughly heated and dried out, then filled with bitumen. Pipes were left in the holes to allow reheating of the bitumen, should it subsequently harden and become ineffective.

To prevent leakage into the subways, watertight seals of bent copper strip were set in the concrete across construction joints completely surrounding the subway.

The effectiveness of the measures adopted to prevent leakage has been demonstrated since the dock and reclaimed area have been opened to tide water, very little leakage occurring into the dock or the subways.

To facilitate the lengthening of the dock, should it ever become necessary,

the east and west walls are prolonged past their intersection with the south wall. The south wall itself is founded not on rock but on top of the extreme and units of the floor.

Plywood was used for formwork throughout, and proved quite satisfactory. The general method of fixing face forms was for the bottom to be held in by profile bolts and the top to be tied back by hooked rods to "hairpins" set in the top of the previous lift. This eliminated the necessity for the use of long profile timbers and considerably lightened the forms, a point of some importance in the 40 feet lengths used on the wall units. The average height of lift was 4 feet.

Except for the reinforced concrete piles, which were made with normal portland cement, low heat cement was used for all parts of the work. The 28 day test results with this cement were generally very satisfactory, but, particularly during cold weather, the concrete was rather slow to harden in the early stages. With regard to the low heat qualities, temperature records taken during the summer in large pours at the bases of the walls indicated a maximum temperature rise of 35° to 40° F.

Concrete mixes used varied from a mix of 4½ cu ft of cement per cu yd with 3 inch aggregate, used for mass concrete in the floor and walls, to a mix of 11 cu ft. of cement per cu yd, with 1½ inch aggregate, for special locations in the culverts where excessive velocities and turbulence might occur.

Slumps generally were restricted to a maximum value of 2 inch to 3 inch, depending on mix and location, and all concrete vibrated with internal vibrators operated by compressed air.

The total quantity of concrete placed in the dock and adjacent structures amounted to some 310,000 cubic yards.

Caisson Grooves.

The caisson grooves were built of granite masonry, some blocks weighing over 4 tons. In the walls, the concrete was kept to a level one course below the masonry, and on the floor a 2 in recess was formed between the back of the stones and the concrete, which was later rammed with a special coarse dry mortar. Although during construction, the blocks were set with great care, it was not possible to achieve the necessary trueness of face, and the grooves were finally dressed with pneumatic tools.

Caissons.

The two caissons were built within the cofferdam alongside the east wharf,

thus overcoming the difficulties of launching craft of such deep draft by making it merely a matter of flooding the dock and entrance basin.

The construction of these was put in hand as soon as the area had been excavated to its final level of 43 feet below datum, and the east wharf completed sufficiently to carry the cranes necessary for handling of steelwork.

The all-welded construction and the rigidity of the design gave rise to some troubles with distortion, but these were satisfactorily overcome by adjustments to the greenheart timber facing.

In September, 1944, as the construction of the caissons had reached a stage sufficiently advanced for them to be floated safely, the main culvert valves had been installed and the pumping machinery was well in hand, and all essential work below tide level completed, the dock was flooded. The water was admitted through the two 21 inch dia pipes previously mentioned, and led by two pipelines across the entrance basin excavation to discharge well inside the dock entrance, to avoid washing material on the floor. These pipelines were carried on floats, and sections uncoupled as the water level rose, until discharge was through the 21 inch dia pipes only.

When flooding was completed, No 1 caisson, which although incomplete, was structurally capable of acting as a gate, was placed in the emergency groove, and the dock pumped out by means of the drainage pumps, the main pumps not yet being available.

Removal of Embankment.

After the caisson and the drainage pumps had proved themselves capable of keeping the dock dry, work was started on the removal of the northern section of the cofferdam embankment, which extended across the entrance basin and prevented the entry of any ship.

The sheet piling wall and the old timber piles of the temporary staging were withdrawn without much difficulty with the aid of special pile extracting gear and a 150-ton floating crane.

The removal of the ballast and clay forming the embankment was carried out by two 4 cu yd draglines working from the top of the bank to about 35 feet below low water, with a ladder bucket dredge removing the balance to the final dredged level of 43 feet below datum.

Fitting out Wharf.

The construction of the fitting out

wharf has been carried out concurrently with that of the dock, but as a separate unit, and is not yet completed.

A temporary timber staging was first constructed along the line of the wharf to carry the cranes, pile frame and other construction plant required.

Steel cylinders of 15 feet diameter were jacked down into the sea bed to a depth of 58 feet below datum, the cylinders being built up in sections as sinking progressed. As the clay inside the cylinders was too tough for excavation with a grab, it was cut up by a diver with a high pressure air and water jet, and removed by an air lift ejector, a method that proved very effective. When excavation in a cylinder was completed, hardwood piles were driven to rock by means of a long steel dolly through centring grids placed at the top and bottom of the cylinder.

During the driving of these piles, it was found that as the later piles were driven, the earlier piles, particularly the four in the centre, rose, in some cases a distance of over 4 inches. This made it necessary to take careful measurements of each pile after it was driven and again after all initial driving was completed. Any piles found to have risen were then redriven. In most cases, the redriven piles finally reached a penetration greater than after their initial driving, although the specified set had been obtained at that time.

After the piles had been driven, concrete was poured round them by tremie to form a plug in the bottom of the cylinder. The cylinder was then dewatered and the remaining concrete placed in the dry.

As the soffits of the beams are below high water level, the construction of these involved tidal work, and was considerably hampered by the continuous presence of fuel oil on the surface of the water.

The rubble bank below the wharf to retain the backfill was placed before the deck slab was poured. Large stones of 10 to 15 cubic feet at the toe and on the outer face was placed by crane and diver while the balance of small size was tipped from trucks running on temporary timber decking.

The framework for the deck slab was supported from the timber piles of the temporary staging, but in many cases these were so badly attacked by marine borers that new piles had to be driven. Holes were formed in the longitudinal beams during construction to facilitate the removal of the deck formwork.

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PHYSICAL PROPERTIES OF CEMENTS

PART II

Factors influencing the Setting properties of Cements

By AMAR NATH PURI, BALWANT RAI and D. D. VOHRA, Punjab University Institute of Chemistry, Lahore.

(Continued from previous issue)

THE physico-chemical changes involved in the process of setting of cements present a fascinating problem of great complexity. It is not possible, for instance, to determine whether this consists in the absorption of water by cement molecules, similar to that which is known to take place in the hardening of gypsum, or whether there is chemical action between the constituents of the cement and the mixing water, giving a solid reaction product. That hardening must consist of some sort of crystallisation and the interweaving of crystal needles was postulated in the first instance by early workers. The advancement of the Science of Colloids gave a new orientation to the problem and several investigators led by Michaelis began to look upon the phenomenon somewhat akin to the hardening of glue, as due to the shrinkage of swollen gels. It must be admitted that this analogy appeared quite fantastic at first and it won its adherents slowly. The greatest obstacle in the way of its acceptance was the fact that the gel, if any, hardened under water, for which there is no parallel among the well known gels of the type of glue. It is, however, supposed that the dehydration and shrinkage of the gel takes place through the slow abstraction of water by the nuclei of cement grains which are gradually hydrated. The dehydration of the gel therefore takes place through "internal absorption". This transformation of the originally formed gel is an extremely slow process and is bound up with the hydration of the cement grains. With coarsely-ground cements several years must pass before the grains are completely hydrated. With more finely ground cements the reaction must proceed more rapidly.

Effect of alcohol on setting of cements.

The "Internal" dehydration of the gel to which the ultimate strength of the cement is ascribed will naturally be affected by the presence of alcohol. A 1:3 mixture of cement sand was worked up with alcohol water mixtures of appropriate concentrations and moulded into hemi-spherical pellets and then allowed to set under alcohol-water mixtures of same concentrations for seven days, at the end of which period, the cohesion was determined in the cohesion testing machine described by Puri* elsewhere. The results given in Table I show that there is a gradual decrease in cohesion up to a concentration of 30 per cent alcohol after which there is a sudden fall and there

is no setting at all beyond a strength of 90 per cent alcohol.

TABLE I.
Cohesion strength of cement-sand mortar when set under different alcohol-water mixtures

Composition of the alcohol water mixture by weight		Cohesion in Pounds
Alcohol	Water	
0	100	76 lbs
10	90	56
20	80	42
30	70	27
40	60	3
50	50	2.5
60	40	2
70	30	1
80	20	0.5
90	10	Nil (no setting)
95	2	Nil (..)

It is well known that alcohol is a powerful dehydrant for colloidal gels, but it is also known to alter the structure of the gel. The abstraction of water by the nuclei of cement grains from the gel would be naturally affected when the cement grains are rapidly dehydrated by themselves by the abstraction of water by alcohol. The effect will be similar if we suppose a rapid drying of the gel itself thus upsetting the slow "internal" dehydration. It is well known that if cement is rapidly dried before it has had time to set then longer keeping will not induce setting. For example the value of cohesion was found to decrease from 267 pounds to 27.5 pounds when the cement pellets in an experiment were rapidly dried in a current of dry air.

In order to see if permanent change has occurred in the cementing gel on contact with alcohol, the cement pellets were kept in contact with 70 per cent alcohol, for 3 days after which they were kept in water for 4 days and cohesion determined. The following results were obtained —

1. Cohesion in alcohol
70 per cent = 5 lbs
2. Cohesion when kept in contact with alcohol for 3 days, and then in water for 4 days.. = 80.3 lbs.
3. Cohesion when directly set under water = 267 lbs.

It will be seen that the capacity of the gel of bonding cement particles is not

altogether impaired on contact with alcohol though it is considerably reduced. These results do not seem to lend support to the gel dehydration theory, though they do not definitely exclude it. It is improbable that the gel be first dehydrated by alcohol and again hydrated by the addition of water to be followed again by dehydration through "internal drying". It is however conceivable that there is some permanent change in the gel structure brought about by contact with alcohol through which its binding property is partially impaired. This is supported by the following set of observations in which cement as such was kept in contact with alcohol for varying lengths of time after which it was worked up with water, made into pellets and allowed to set under water in the usual way, after which the cohesion was determined. The results are given in Table II.

TABLE II.
Effect of keeping cement in contact with alcohol for different intervals of time, on its setting in water

Time of contact w.th Alcohol	Cohesion force
0 hour	267 lbs.
1 hour	100 ..
2 hours	99.2 ..
4 ..	99.5 ..
8 ..	84.0 ..
12 ..	79.0 ..
16 ..	70.8 ..
24 ..	72.2 ..
36 ..	74.3 ..
48 ..	72.0 ..

Table II shows that there is a rapid fall in cohesion even on contact with alcohol for an hour. Longer contact induces lesser decrease which is completed in about 16 hours after which there is practically no change, the cohesion having been reduced to less than 30 per cent of the original value.

The results indicate that some sort of gel formation must be the cause of setting of cement, whether internal dehydration of the gel takes place or not is not clear.

If the setting of cement is due to the internal dehydration of gel by the nuclei of cement grains, then the rate of setting must be reduced in the presence of coarser particles. This is actually the case as is apparent from the results given in Table III, which show that not only the final strength is low, but the rate of setting is considerably reduced when the percentage of sand is increased in the

* Puri, A. N. 1937—“Physical Characteristics of Soils” Part I, Soil Science, 44, 343

mixture. If the dehydration was a spontaneous process inherent in the gel, then one would have expected that though the final strength might be reduced the rate of setting would be unaffected.

TABLE III
Strength of cement when allowed to set in water for different intervals of time

Time in hours.	Cohesion in pounds		
	Pure cement	Cement Sand 1:1	Cement Sand 1:3
2	No setting	No setting	No setting
4	4 lbs.	"	"
6	7	1.5 lbs.	"
8	7.5	4	"
12	24.5	10	3 lbs.
15	30.0	"	"
18	48.0	25.6	"
21	120.0	"	"
22	163.0	52.2	26.0
24	200.0	98.0	"
30	307.0	33.6	"
39	266.0	"	"
44	167.4	123.0	36.5
46	"	135.0	39.0
48	"	133.5	39.0
50	"	134.5	"
54	"	40.0	"
60	"	40.3	"
66	"	46.0	"
72	"	56.3	"
78	"	56.0	"
84	"	60.0	"
90	"	63.0	"
96	"	67.0	"
102	"	76.0	"
108	"	77.0	"

In order to find out if any chemical combination takes place between cement and alcohol, 5 gms. of a sample of cement was kept in contact with alcohol for some time and then dried after filtration in a current of dry air. The sample was weighed and then dried in an oven at 110°C and loss of weight determined which was found to be 2.26 per cent. In order to make sure that this loss was not due to any alcohol that may not have been driven out by air, the loss in weight of a sample of air dry cement was determined in the oven. It was found to be 1.12 per cent. The difference in the two values is too small to indicate any alcoholate formation.

Another line of attack on the problem of dehydration of the gel during setting was to follow the change in sizes of the capillaries in cement during setting. This can be done with the help of the capillarimeter devised by Puri*. The cement is held in a sintered glass funnel and connected through a pressure tubing to a burette the level of which is gradually lowered to subject the cement to increasing pressure deficiency until it exceeds the capillary pull of the cement pores when the continuous liquid column is broken due to the ingress of air through the capillaries. The size of the capillaries is inversely proportional to the pressure deficiency at the break point. Neat cement as well as 1:1 and 1:3 cement sand mixtures were tried and the capillary pull at the break point is recorded in terms of centimeters of mercury at different intervals of time. The results given in Table IV bring out the interesting fact that the maximum capillary pull decreases at first and then gradually increases. The maximum value is

reached after a longer interval of time in the case of cement and mixtures than in the case of neat cement.

the capillary pull over a longer time. The results are given in Table V. This would be expected from the fact

TABLE IV
Change in Capillary pull of Cement during setting under water

Time after which capillary height was taken	Capillary height in terms of cms. of mercury					
	Pure Cement		Cement Sand. 1:1		Cement Sand 1:3	
	Height cms. of Hg.	Remarks	Height cms. of Hg.	Remarks	Height cms. of Hg.	Remarks
0-10 Mts	45.0	No setting	23.0	No setting	8.0	No setting
15-25 "	27.0	"	19.0	"	8.0	"
30-40 "	21.0	"	19.0	"	8.0	"
60-70 "	23.0	"	20.0	"	8.0	"
2 hours	25.0	"	21.0	"	"	"
3 "	25.5	"	"	"	"	"
4 "	26.0	"	"	"	8.0	"
5 "	26.0	"	"	"	"	"
6 "	28.0	"	21.5	No setting	7.0	No setting
8 "	28.5	"	"	"	"	"
10 "	42.0	Setting noticed but not so hard	22.0	No setting	"	"
12 "	44.0	Hardness was greater.	22.0	No setting	"	"
14 "	45.0	"	"	"	8.0	No setting
16 "	49.0	"	22.0	No setting	"	"
18 "	63.0	Very hard	23.0	"	"	"
22 "	"	"	40.0	Setting noticed but not so hard	9.0	No setting
24 "	65.0	Very hard.	"	"	"	"
28 "	64.0	"	"	"	"	"
36 "	"	"	41.0	"	"	"
44 "	"	"	43.0	Hardness was greater	"	"
48 "	"	"	46.0	Very hard	11.0	No setting
52 "	"	"	47.0	"	12.0	"
60 "	"	"	"	"	13.0	Slight amount of setting noticed.
72 "	"	"	"	"	16.0	"
84 "	"	"	"	"	18.5	"
96 "	"	"	"	"	19.5	Fairly hard.
100 "	"	"	"	"	20.0	"
104 "	"	"	"	"	21.0	Hardness greater
110 "	"	"	"	"	25.0	"
114 "	"	"	"	"	26.5	Very hard.
118 "	"	"	"	"	28.0	"

The reaching of the maximum value also coincides with the time when the cement is set hard. If the setting of the cement is due to the dehydration and shrinkage of the cementing gel then one would expect a continuous increase in the size of the capillaries and a continuous decrease in the maximum capillary pull. It is not unlikely that the dehydration of the gel is accompanied by the hydration of cement grains. The primary decrease in the capillary pull must be due to the setting of the gel in the minutest pores and points of contact between the particles. This is followed by the gradual dehydration of the gel which will recede to the still finer pores. At the same time the larger grains would get hydrated at the expense of the dehydrating gel and the larger pores will thus be reduced leading to an increase in the capillary pull. Similar experiments with alcohol showed that there is no change in

that there is no setting of cement under alcohol and changes in the pore sizes apparently only take place during the process of setting.

If the setting of the cement is due to the dehydration and shrinkage of the gel through the slow abstraction of water by the nuclei of cement grains then this dehydration could be easily prevented by shaking the cement violently with water, which would keep the individual grains apart. Under those conditions the gel should not get dehydrated and its dehydration should commence only when it is rendered into a compact mass by bringing the particles in intimate contact. If this view is correct there should be no effect on cohesion. Actually this is not the case and there is considerable reduction in cohesion if the particles are kept in contact with water under condition of violent agitation either by a mechanical stirrer, or by shaking with

* Puri, A.N. 1939—"The Capillary tube hypothesis of soil moisture"—Soil Science, 48 505.

TABLE V.
Change in capillary pull of Cement during setting under alcohol.

Time after which capil- lary height was deter- mined	Capillary height in terms of cms. of Hg					
	Water 33°		Alcohol 70%		Water 50°	
	Height	Remarks	Height	Remarks	Height	Remarks
0-10 Minutes	9.5	No setting	12.0	No setting	25.0	No setting
30 Minutes	0.0	"	12.0	"	22.0	"
2 hours	0.0	"	12.5	No setting	20.0	"
6 "	0.0	"	12.0	"	19.5	"
10 "	0.0	No setting	12.0	"	20.0	"
12 "	9.5	"	13.0	"	21.0	"
18 "	0.0	"	12.0	"	20.0	"
24 "	9.0	No setting	12.5	No setting	22.0	"
36 "	9.5	"	12.5	No setting	24.0	"
48 "	0.0	"	12.5	No setting	23.0	Slightly set
56 "	9.0	No setting	13.0	No setting	27.0	"
72 "	9.5	"	13.0	No setting	22.0	Fairly hard.
84 "	0.5	"	13.5	"	33.5	Hardness greater
96 "	9.5	"	14.5	No setting	35.0	Quite hard
112 "	9.5	"	16.0	No setting	36.0	"
124 "	0.5	"	16.0	"	39.5	"

sand or by boiling. Effect of stirring for varying lengths of time on cohesion is shown in Table VI. The cohesion is reduced from 267.0 lbs to 30 lbs in 30 hours. On shaking with sand for 24 hours the cohesion was reduced to 152.5 lbs. The results of boiling are also given in Table VI.

TABLE VI.
Effect of various treatments on cohesion of cement in water

Treatment	Cohesion in lbs
No treatment	267 lbs
Violent stirring for 8 hours	92.5
" " 12 "	82.5
" " 20 "	58.5
" " 30 "	30.0
Boiling cement for $\frac{1}{2}$ hour and then setting in water	80.0
Boiling cement for 1 hour and then setting in water	24.0
Boiling cement for 2 hours and then setting in water	13.5
Boiling cement for 4 hours and then setting in water	5.3
Boiling cement for 6 hours and then setting in water	1.6
Boiling cement for 8 hours and then setting in water	No pellet could be formed.
Shaking with coarse sand in water for 24 hours	152.5
Shaking with coarse sand in alcohol and setting in water	82.5

It will be seen that in all cases the cohesion is considerably reduced and on boiling especially it becomes non-setting. If the setting was due to dehydration of the gel it is inconceivable that any such dehydration should take place in the presence of large excess of water and in the absence of cement grain nuclei. We are, therefore, forced to the conclusion that whatever changes the gel undergoes must be inherent in itself and would take

place irrespective of the presence of grain nuclei. The idea of internal dehydration, therefore, is not supported by these facts. The changes in the structure of the gel must be supposed to take place spontaneously in the presence of water and must be considered irreversible. Further, the setting of cement is not associated with its state of aggregation, each individual grain must be supposed to be undergoing the change associated with setting.

A rise of temperature during the process of setting must adversely affect the setting since boiling with water permanently impairs the setting property of cement. This will be clear from the results given in Table VII, in which are recorded the cohesion values of cement allowed to set at 3 different temperatures for 36 hours.

TABLE VII
Effect of temperature on setting of cement.

Setting of cement for 36 hours in water at a temperature of 22°C	267 lbs
Setting of cement for 36 hours at a temperature of 60°C in water	147.5
Setting of cement for 36 hours in water at a temperature of 90°C	45.0

The presence of free lime in cement plays an important part in its setting properties, its removal must therefore result in a considerable decrease in cohesion. The sample of cement under examination contained about 60 per cent. of lime. Increasing amounts of lime were precipitated as calcium oxalate and calcium carbonate by the addition of oxalic acid or by passing carbon dioxide gas. The cohesion of the resulting mass was determined in the usual way. The results are given in Table VIII. It will be seen that when even

6 per cent lime (*i.e.* 10 per cent of the total) is removed the cohesion is reduced to a little over 10 per cent of the original value. When 30 per cent. of lime is removed the cement has completely lost its power of setting.

TABLE VIII
Effect of removal of CaO on cohesion of cement in water

% of CaO removed	Cohesion in lbs.
0% of CaO removed	267 lbs
6% of CaO removed by oxalic acid	30
12% Do	12.5
21% Do	4.0
30% Do	No pellet formation
48% Do	do
60% Do	do
After passing CO ₂ for $\frac{1}{2}$ hour to precipitate CaO as CaCO ₃	65.7 lbs.
After passing CO ₂ for 1 hour to precipitate CaO as CaCO ₃	42.0
After passing CO ₂ for 2 hours to precipitate CaO as CaCO ₃	27.5

When lime was added in amount equivalent to that removed in case of 12 per cent and 30 per cent of removal of CaO the cohesion was found to increase from 12.5 to 28.5 and from zero to 24.6 pounds respectively. This shows that cement can recover only a part of its strength on adding lime after its removal.

If the setting of cement is due to internal dehydration then the effect of coating cement particles with wax would result in a total inhibition of its setting properties because the wax coating would prevent the transfer of moisture and dehydration would not take place. Cement particles were coated with wax by adding 5cc of the paraffin wax solutions in benzene of different concentrations to 10 grams of the cement and the resulting mass was worked up with water and its cohesion determined in the usual way. The results given below show that upto 3 per cent wax solution there is no effect after which the cohesion is reduced considerably.

Treatment	Cohesion (lbs.)
No coating	267.0
2% wax	265
3% wax	266
4% wax	115.5
5% wax	57.0

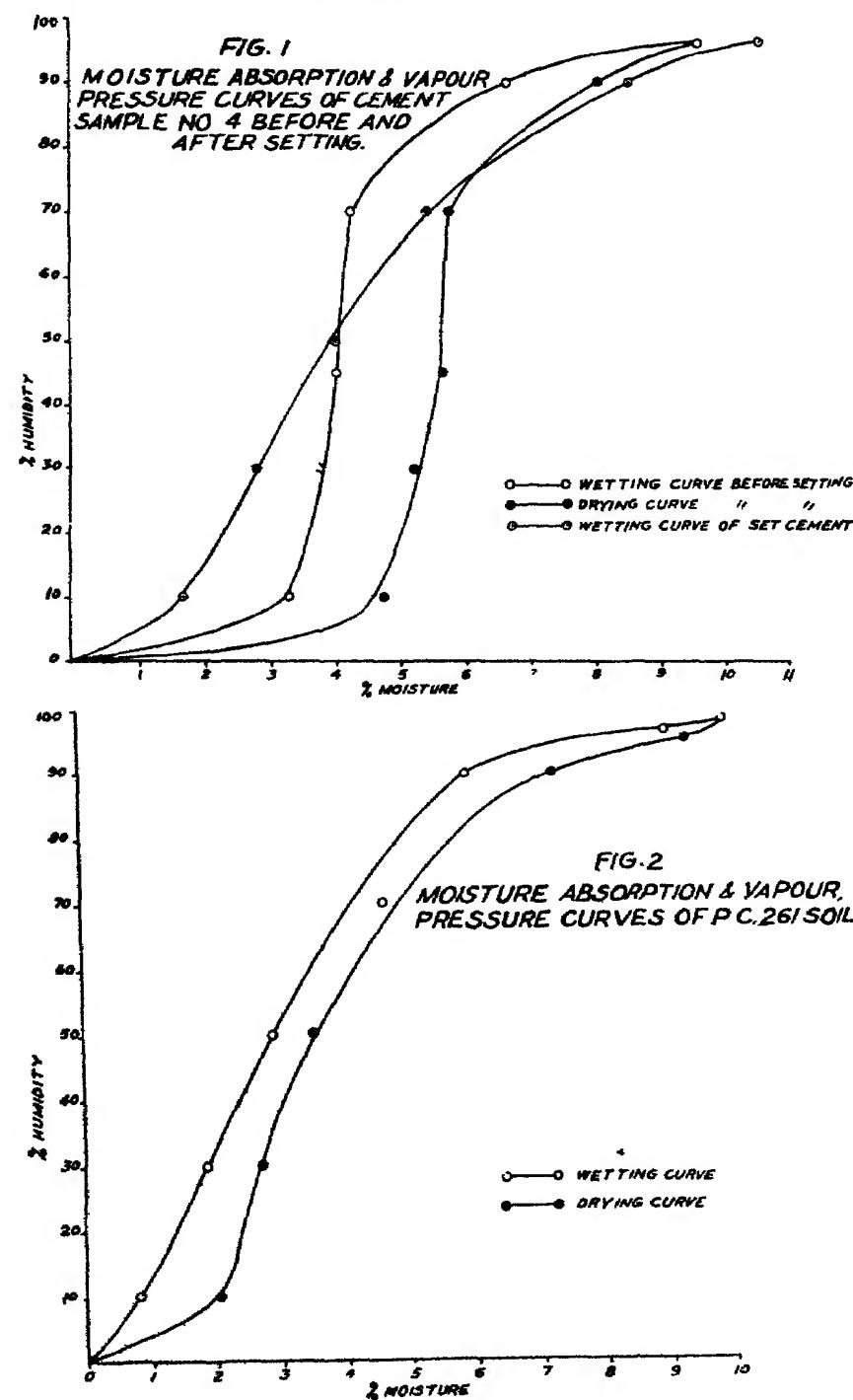
The fact that treatment with 3 per cent wax solution has absolutely no effect supports the contention that the hypothesis of internal dehydration is untenable. One would have expected much greater reduction even on the addition of small quantities of wax. These results support the contention that the gel must be supposed to undergo changes irrespective of the presence of other particles and when the amount of wax is further increased the reduction in cohesion is merely due to the presence of weaker bond like that of wax between the adjacent particles otherwise it can have no effect on the course of setting.

Effect of moisture absorption from a humid atmosphere on the setting properties of cement.

It is well known that all substances with a capillary structure absorb varying amounts of moisture from atmospheres of different humidities. This is purely a physical phenomenon and is due to the condensation of moisture in the minute capillaries. The relation between moisture content and relative humidity is perfectly defined for any given substance within the hysteresis loop. The equilibrium moisture content is always higher

TABLE IX
Moisture Absorption by soil and Cement from atmospheres of different humidities.

	10%	30%	50%	70%	90%	96%	99%
Soil No 261							
Wetting curve	0.79	1.78	2.86	4.54	5.82	8.88	9.80
Drying curve	2.00	2.65	3.40	4.55	7.12	9.22	9.80
Cement No. 4							
Wetting curve	3.28	3.75	4.08	4.23	6.64	9.51	9.65
Drying curve	4.77	5.14	5.65	5.75	8.05	9.35	9.65
Set cement	..	1.64	2.77	3.97	4.89	8.49	10.5



when the substance is brought from a higher to a lower humidity than *vice versa*. A typical curve for soil is shown in Fig. 2; A similar curve for Cement is shown in Fig. 1 which is plotted from the data given in Table IX for cement No 4. The two curves though showing a general similarity in shape are essentially different in the sense that whereas in the case of soil the absorption is gradual, it is not so in the case of cement, in which, the major absorption takes place in an atmosphere of 10 per cent humidity. The interval between 10-70 per cent humidity is characterised by very little moisture absorption after which there is further absorption up to 98 per cent humidity. When the cement is allowed to set and then wetted in atmospheres of increasing humidity, there is a general decrease in hygroscopicity up to 50 per cent humidity after which the two curves cross each other. It is clear that the distribution of capillaries in the sample after setting is more uniform, there is a decrease in the smaller capillaries and a corresponding increase in the larger ones, which would be expected from the general physical changes that result in imparting hardness to cement on setting.

TABLE X

Cohesion of Cement after allowing it to take up moisture from atmospheres of different humidities

% humidity	Cohesion force in lbs
0	267
10	269.5
30	260.0
50	264.5
70	250.0
75	264.5
80	178.2
85	88.0
90	75.5
95	68.0
98	57.0

The cohesion values for cements kept in atmospheres of different humidities are still more interesting (Table X). There is hardly any effect up to 75 per cent humidity, but there is a considerable decrease in cohesion when cement is kept in an atmosphere of 80 per cent humidity and then worked up with water and allowed to set in the usual way. Above 80 per cent humidity there is a rapid fall, in cohesion leading finally to a value 20 p r cent of the original at 98 per cent humidity. The critical

humidity of 75 per cent. is of great practical importance. It shows that in dry places where the relative humidity seldom goes above this value there would be no danger of the deterioration of cement, but if there is any likelihood of the humidity rising above 75 per cent in any locality, cement must be protected from the atmosphere. Waxing the cement particles, by treatment with a solution of wax in benzene leads to a decrease in moisture absorption (Table XI and Fig. 3) but does not render it completely impervious. This is in agreement with the cohesion measurements which showed some reduction, but not complete inhibition of the setting property.

The results of moisture absorption throw a good deal of light on the mechanism of setting. If moisture absorption from an atmosphere of 80-85 per cent humidity leads to such an enormous decrease in cohesion, it only shows that the changes in the gel structure that are responsible for cohesion have already taken place in this humidity. Setting therefore, is not a process of "dehydration" internal or external, but hydration of a sort. The possibility of gel formation is not excluded and cannot be denied but there is no evidence to prove its subsequent shrinkage through dehydration. The mechanical strength accompanying setting is possible through the ageing of the gel structure, the possibility of slow coagulation or flocculation of the colloidal gel in the minute interstices between the particles is not excluded and is very likely the cause of the mechanical strength associated with setting. One has only

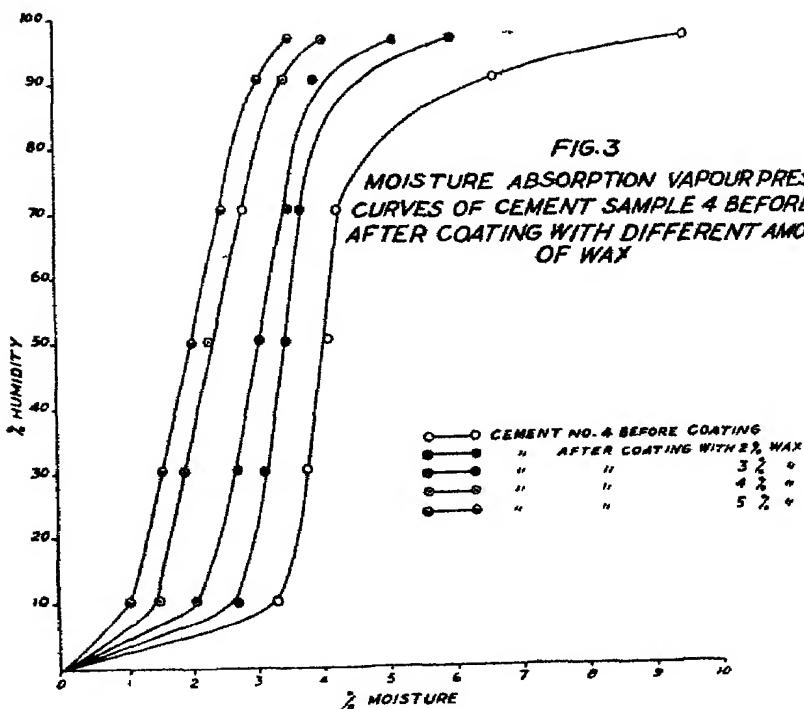


FIG. 3
MOISTURE ABSORPTION VAPOUR PRESSURE CURVES OF CEMENT SAMPLE 4 BEFORE AND AFTER COATING WITH DIFFERENT AMOUNTS OF WAX

to recall the formation of bones in the human body or remember the extreme hardness of mammalian teeth to realize how slow coagulation of calcium phosphate can lead to the formation of hard structures. We are only reproducing in

the case of cement what nature is doing on a vast scale in providing supporting frame-work for all higher forms of life.

S U M M A R Y .

Various factors influencing the setting properties of cement have been studied with a view to understand the mechanism of the process of setting. The data collected does not lend support to the existing view that the hardening of cements is due to shrinkage and slow internal dehydration of the originally formed swollen gel. It appears, though the evidence is by no means conclusive that the ageing of the gel and its coagulation in the minute interstices of cement particles is primarily responsible for the setting of cements.

TABLE XI.
Moisture absorption by Cement after coating it with different wax solutions.

	10%	30%	50%	70%	90%	96%
Cement No. 4						
No coating	3.28	3.75	4.08	4.23	6.64	9.51
After coating with						
2% wax solution in benzene	2.74	3.15	3.47	3.71	4.07	5.97
3%	"	2.04	2.70	3.05	3.51	3.95
4%	"	1.52	1.91	2.29	2.84	3.48
5%	"	1.06	1.51	2.03	2.57	3.09

(Continued from page 106.)

determine at a later date the efficiency of this mudjacking after plant-mix blankets had been placed.

This entire mudjacking program was under the immediate direction of Maintenance Foreman E. C. Van Schaick.

Mr. Cooper reports that he received a letter from a Canadian engineer in which he stated that one of his big difficulties in drilling holes through concrete pavement lay in the fact that the ordinary jack hammer breaks a cone off the bottom of the pavement about 4 in. thick and 14 in. or 15 in. in diameter. To overcome this, he used a diamond drill outfit which is much more expensive than the ordinary jack hammer method. Mr. Cooper reports that he had the same difficulty in drilling holes through the pavement, although the cone that broke off the bottom of the pavement was not over 1 in. thick and seldom was more than



3 in. to 4 in. in diameter.

"By experimenting," continues Mr. Cooper, "we found that by using sharp bits and by not exerting any force on the jack hammer, but merely allowing

the weight of the 55-lb. hammer to do the drilling, the difficulty was overcome. On the average we change bits every 15 to 20 holes." (With acknowledgment to "Concrete")

MUDJACKING CONCRETE ROADS IN CALIFORNIA . . .

FOR the past two years an extensive mudjacking programme has been under way in District V of the California Division of Highways. The programme, started in 1943, was stepped up this year considerably in an effort to arrest the increasing number of "step-offs" in portland cement concrete pavements at joints and cracks resulting from pumping action induced by more than normal repetitions of heavy wheel loads.



The first work done was in Santa Clara County along US 101 on 12 different sections where step-offs were noticeable. Since then the programme has been materially increased, and to the point where the division of highways' maintenance forces have been able to incorporate in the procedure several details worth particular attention.

The following information has been supplied by H L Cooper, District V maintenance engineer.

The drilling crew equipment consisted of a 370-cu ft air compressor, one 3-cu yd dump truck, two 60-lb hammers, and one pickup truck.

The mudjacking equipment consisted of a utility paint truck with compressor, one 3-cu yd dump truck for hauling mud, one 6-ton trailer, one 1-sack concrete mixer, one 7-cu ft mud container, and one express car.



The material used at the beginning of the work was selected roadside material with the following screen analysis:

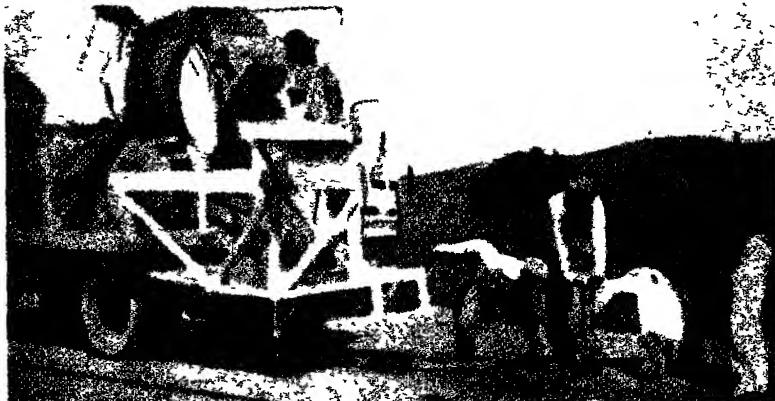
Screen	Passing	Per cent
16	100	With a moisture equivalent of 19.6
30	99	per cent and linear shrinkage of 0.8 per cent
50	76	
100	14	
200	6	
270	5	

The combined mud mixture consisted of 1 cu yd. of sand, 5 sacks of cement, 100 lb of diatomaceous earth, and 56 gal of water, giving a combined weight of about 3,440 lb. A total of 1,100 holes was filled with this material, but after the work progressed farther, it was found that a better sand material could be purchased from a commercial plant at \$1.20 per cu yd. This gave better results in the combined mix. Thus material had the following screen analysis:

Screen	Passing	Per cent
8		100
16		94
50		76
100		14-20

The combined mud mixture consisted of 1 cu yd of sand, 5 sacks of cement, 32 to 64 lb of diatomaceous earth, 92 to 116 gal of water and 50 to 100 lb. of plaster of Paris, giving a combined weight of about 3,500 lb.

Experimenting was done with this material to obtain a workable mix that would flow freely into the voids, and have an initial set soon enough so that traffic passing over freshly filled areas would not force the mix out from under



the pavement. The addition of the plaster of Paris set up the mix in 15 to 35 min., while before its addition, several hours to a day were required before a set was obtained.

It was found that in areas with small voids better results were obtained by increasing the diatomaceous earth content to 64 lb per cu yd, and by decreasing the plaster of Paris to 50 lb, which also increased the water content necessary to 116 gal per cu yd.

When large voids were encountered, 32 lb of diatomaceous earth and 100 lb of plaster of Paris were used, which allowed traffic to move over these distressed areas in a very short time without any visible effect on mud content.

After moving to Santa Barbara County in the southern part of the district,

the cost of trucking the entire amount of sand required from the commercial plant at Atascadero was so high that a commercial sand in Santa Barbara was mixed with the Atascadero sand on a 33 $\frac{1}{2}$ to 50 per cent basis. This gave satisfactory results.

Newer Work.

The addition for this year's work of a 6-ton trailer 16 \times 7 ft in size, was an important factor in more efficient operation as all of the mudjacking equipment was placed on this trailer, which acted as one unit. Two 300-gal water tanks were placed on the front of the trailer, and a 1-sack concrete mixer on the rear. Suspended from the extreme rear and slightly lower than the mixer, the 7-cu ft mud pot was placed. After being mixed, the material was poured into this pot, first being strained through a screen to remove lumps and foreign material. This mud container was converted from a sand container from a bridge sand-blasting outfit, and



age of 419 holes drilled per day at a cost of 20¢ per hole. The average drilling cost per day was \$82.59.

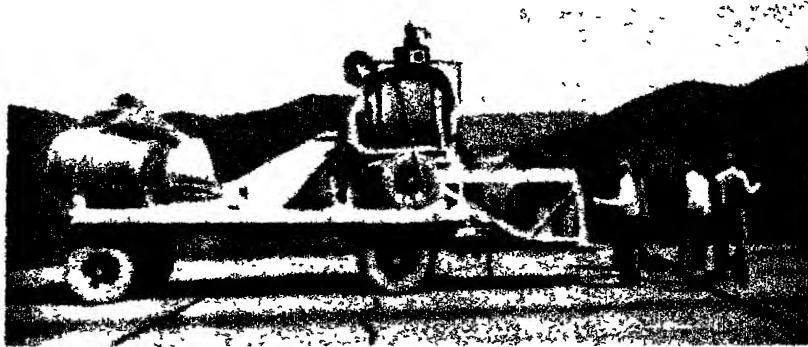
Mudjacking these 13,839 holes required 50 working days, or a total of 276 holes filled per day at a cost of 82¢ per hole. The average filling cost per

day was \$227.50. For the entire work the cost of drilling and filling was \$1,02 per hole.

About 3.74 cu yd of material was used per day and an average of 0.37 cu ft material was forced into each hole, although there was a variation of from 0.1 cu ft to 7.0 cu ft per hole.

For the first portion of the work, two holes were drilled in each expansion and dummy joint per panel with no attempt made to raise the depressed slabs to grade. As the work progressed it was decided to raise the depressed slabs and the locations of the holes were changed to from 6 in to 12 in away from the joints, two holes per panel, and drilled 4 in below the bottom of the pavement.

It was found that a larger amount of mud could be forced into each hole and the low slabs raised to grade fairly easily. The reason for this is probably due to the fact that where the crack filling material had become broken or was missing in the immediate area of



only one change was necessary—a 2-in lubricator valve was placed at the exhaust end and a 1-in heavy-duty rubber hose 10 ft long was attached to this valve. The nozzle on the end of the hose was a piece of rubber hose, 6 in long with an outside diameter slightly less than the diameter of the drilled holes. When the nozzle was placed in the hole, the pressure would swell the hose to a tight fit, allowing no escape of pressure or mud. A pressure of 80 psi was found to be the most satisfactory at the compressor.

Cost Data.

A total of 13,839 2-in holes was drilled in 33 working days or an aver-



the hole, pressure was lost through this opening, and it was then impossible to force very much mud under the slab. Also, in many cases the panels have the low areas at the joints, and, as the slabs are resting on the subgrade, there are no voids to fill at this point.

Redwood pegs 3 \times 3 \times 10 in with sharpened ends were used to plug adjacent holes when pressure was desired to lift depressed slabs. An examination after two weeks showed that these raised slabs were still at grade.

A chart on cross-section paper was kept showing the location of all holes by station and distance, in from the edge and distance from the joint, in order to

(Continued on page 104.)



SHEAR REINFORCEMENT IN COLUMN BASES

By W. T. MARSHALL, Ph.D., A.M. Inst. C.E., A.M.I.Struct.E.

THE isolated column base, square in plan, is undoubtedly the commonest form of reinforced concrete foundation. The load from the column is spread by means of the base over such an area that the permissible bearing pressure of the ground is not exceeded. The spreading of the load produces bending moments and shearing forces in the base. A typical base is shown in Fig. 1.

The usual criterion for designing against shear is that given in By-Law 99 of the L.C.C. Building Act (Amendment) Act, 1935, namely, that the punching shear stress, that is, the shear measured along the planes XX_1 , must not exceed

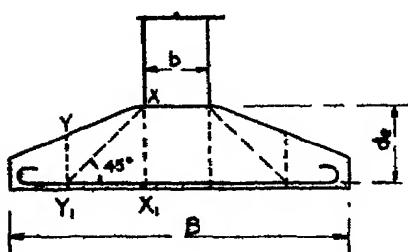


Fig. 1

twice the permissible shear in plain concrete. The Code of Practice makes no mention of shear stresses in column bases, and the omission was probably not purposeless. Clause 810 (a), however, if applied to column base design, would specify that the shear force along the planes YY_1 must not exceed the permissible shear in plain concrete. Clause 801 (a) states that the clauses in section 8 only apply to a series of rectangular slabs arranged in three or more rows, and in the Code alone there is no justification for applying clause 810 to column bases. There is, however, a strong weight of theoretical and experimental argument in favour of taking the planes YY_1 as the critical section for shear.

If not limited, the base is made of a depth that keeps the shear stresses within the permissible limits, and the question of reinforcement against shear never arises. There may, however, be cases where due to various causes the depth of the base is limited and the shear stresses exceed their allowable values. In such circumstances the bases must be reinforced against shear in addition to the tensile reinforcement used against bending.

Text-books seldom refer to shear reinforcement, and the objects of this article are to give the type of reinforcement which the writer believes to be correct and to point out the fallacy in using a form of reinforcement which is sometimes included in designs.

The Fallacy of Using Bars in the Top of the Base.

The method used by some designers to reinforce against punching shear is to

place bars in the top of the base as shown in Fig. 2A. The amount of reinforcement required is calculated as follows:

Let the column load be P lb and the safe shearing stress in steel 13,500 lb per square inch, then the area of reinforcement required in each direction is

$$P / 4 \times 13,500 \text{ sq in}$$

This is a conservative estimate and assumes that all the punching shear is taken by the reinforcement. Some designers deduct from P the load which can be taken by the base when the punching shear stress reaches its limiting value. This method requires much less reinforcement.

The writer knows of one large building where the column bases were reinforced in this way, and as the building has stood the test of time the designers may claim some justification for the method. An examination of the forces coming on the bars, however, shows that they cannot carry the shear force without either causing excessive crushing in the concrete immediately below them or excessive bending stresses in themselves.

Consider one of the bars as shown in Fig. 2B. Let the width of the column be b in and the length of the bar l in

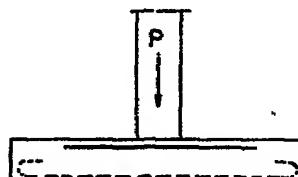


Fig. 2A.

where l varies generally from 3.5b to 4b. The downward load coming on the bar is that proportion of the column load which it carries. This must be balanced by an equal upward reaction which causes compression between the bar and the underlying concrete. The exact distribution of this upward reaction is unknown, but it will obviously be greatest in the vicinity of the column load and smallest at the ends of the bar. An assumed distribution to satisfy these conditions is shown in Fig. 2B.

If the bar diameter is d and a 1:2:4 concrete is used for the base, the maximum value of the intensity of upward pressure is 600 lb per inch run.

$$\text{The total downward load} = (2 \times 13,500 \times \frac{\pi}{4} \times d^2) \text{ lb}$$

$$\text{The total upward pressure} = 600b/d + 300d(l - b)$$

Equating these gives $212d = 6b + 3(l - b)$. Taking $l = 3.5b$ gives $l = 55d$. This is the minimum bar length required to keep the compressive stress between the bar and the underlying concrete within its safe limit of 600 lb per square inch.

The pressure distribution shown in Fig. 2B produces bending stresses in the bar, and the maximum bending moment occurs at X . Let M be this bending moment. Then $M = 300d \times (l - b)^2 \times \frac{1}{12}$. Taking $l = 3.5b$ and using the minimum embedment $= 55d$ gives

$$M = 38,800d^3 \text{ in-lb}$$

$$\text{The extreme fibre stress in the bar} = \frac{M}{Z} = \frac{38,800d^3 \times 32}{\pi d^3} = 395,000 \text{ lb per square inch}$$

This is much greater than the ultimate strength of mild steel, which shows that the assumed distribution of pressure in Fig. 2B is wrong. But this pressure distribution with $l = 55d$ is necessary in order to keep the compressive stress in the concrete within the safe limits. Therefore the bar cannot take a shear stress of 13,500 lb per square inch and at the same time satisfy the conditions of static equilibrium with steel and concrete not overstressed.

In the method described the stress in the steel is sometimes taken as m times the safe punching shear stress in plain concrete. With Ordinary Grade 1:2:4 concrete having a safe punching shear

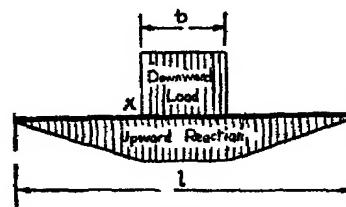


Fig. 2B.

stress of 150 lb per square inch, and taking the L.C.C. value $m = 15$, the shear taken by the bars is 2,250 lb per square inch. Even with this low shear stress the bending stresses in the reinforcement cannot be kept within their safe value unless the diameter of bar used is greater than $\frac{b}{4}$, an absurdly high figure.

It remains, however, to explain the fact that in practice such reinforcement has appeared to be effective.

Punching Shear Failures Unlikely.

The writer carried out many experiments on thin-section column bases in an endeavour to produce a failure by punching shear* and found that when a base failed due to excessive shear the fracture plane sloped away at 45 deg from the column face as shown in Fig. 3A. This type of failure confirms the application of Clause 810 of the Code to column bases and justifies the omission of any clause about punching shear. One very obvious reason, therefore, for the apparent efficiency of the bars in the top of the

* Journal of Inst.C.E. March 1944, "Experiments on Reinforced Concrete Column Bases".

slab is that they reinforce against a type of failure which never occurs.

Some experiments were carried out on bases having a mesh of reinforcement in the top, and it was found that these did carry a greater load than a similar base without the top mesh. The reason for the increased load seemed connected with the type of failure, the fracture-surface being as shown in Fig. 3a, and it is seen that this covers a great area than that in Fig. 3a. This increase in load was however, not large and was not comparable with that which should have been obtained had the reinforcement taken shear in the ways already discussed.

In a very extensive series of tests on column bases by Talbot * the only shear failures produced were those along the 45 deg. planes shown in Fig. 3a. Experiments certainly show that failure by punching shear never occurs.

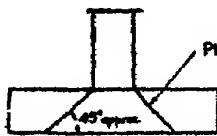


Fig. 3a.

Consequently, in a column base, failure due to shear is to be expected along the planes on which the tensile forces act, namely, planes inclined at 45 deg. to the vertical. Failure along the vertical planes XY_1 (Fig. 1) would only take place in a column base if concrete were weaker in shear than in tension (Failures of the punching type do occur in steel which is weaker in shear than in tension; for example, the punching of rivet holes in members). Since failure is going to take place along the planes XY_1 , the best form of shear reinforcement will be perpendicular to these planes.

Reinforcement against Failure on 45 deg. Plane.

If the shear stress calculated on the planes XY_1 exceeds the permissible shear in plain concrete, then shear

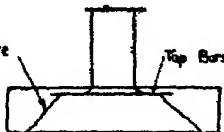


Fig. 3b.

Theoretically one would never expect punching shear failures in concrete, for it has to be remembered that a shear stress is always accompanied by equal tensile and compressive stresses on planes inclined at 45 deg to the plane of the shear stress. The failure of a material under loads which produce shear stresses depends on which of the three types of stress first reaches its critical value. For example, in the thin web of a plate-web girder it is the compressive forces which cause failure, and this is shown by buckling of the web. When a solid steel bar is twisted, however, the ultimate shear strength is reached before the ultimate compressive strength, and failure takes place on a plane perpendicular to the axis of twist. Since plain concrete is weaker in tension than in shear or compression, any failure under shear takes place along the plane on which the tensile forces act. Thus in beams shear failures are shown by cracks which are inclined at 45 deg to the vertical, and when a concrete member is twisted the fracture-surface is a helix inclined at 45 deg to the axis of twist.

* University of Illinois Bulletin No. 67, "Reinforced Concrete Wall Footing and Column Footings," by A. N. Talbot.

$$\text{Area of spread} = 12 + 2 \times 16.5 = 33 \text{ in}$$

$$\text{Total shear} = 80 \times 2,240 \times \left(1 - \frac{2.75^2}{7^2}\right) = 151,000 \text{ lb.}$$

$$\text{Unit shear on planes } YY_1 = \frac{151,000}{4 \times 10.5 \times 33} = 109 \text{ lb per square inch}$$

$$\text{Area of reinforcement in each quadrant} = \frac{151,000 \times \sqrt{2}}{4 \times 18,000} = 2.96 \text{ sq. in}$$

Use seven $\frac{3}{8}$ -in. diameter bars arranged as shown in Fig. 4.

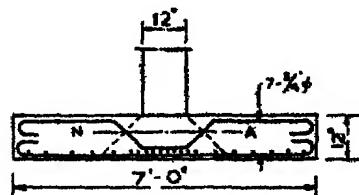


Fig. 4.

Example 2.

A column 18 in. square carries a load of 200 tons and rests on a base 9 ft square and 18 in. deep of 1:2:4 Ordinary Grade concrete.

$$\text{Area of spread} = 18 + 2 \times 16.5 = 51 \text{ in}$$

$$\text{Total shear} = 200 \times 2,240 \left(1 - \frac{4.25^2}{9^2}\right) = 347,000 \text{ lb}$$

$$\text{Unit shear on planes } YY_1 = \frac{347,000}{4 \times 16.5 \times 51} = 103 \text{ lb per square inch}$$

$$\text{Area of reinforcement in each quadrant} = \frac{347,000 \times \sqrt{2}}{4 \times 18,000} = 6.73 \text{ sq. in}$$

Use eleven $\frac{3}{8}$ -in. diameter bars arranged

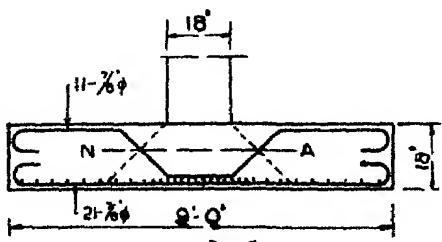


Fig. 5.

as shown in Fig. 5—(With acknowledgments to "Concrete and Constructional Engineering.")

CONTRIBUTIONS

Articles and photographs suitable for publication in *The Indian Concrete Journal* are always welcome, and those that are accepted, will be paid for at our standard rates.

MULTIPLE-ARCH BRIDGE OVER THE SPILLWAY OF GRAND COULEE DAM.

THE spillway bridge over Grand Coulee dam is a reinforced concrete multiple-arch structure. It was designed by the Bureau of Reclamation and constructed by Consolidated Builders, Inc. Construction of the bridge was started in July, 1941, and it was completed in November, 1941. Fig. 1 is a view of the bridge from the downstream side. The following notes are taken from a paper read before the American Concrete Institute by Mr E R Dexter, engineer in charge of the Design Section of the Bureau's Division of Dams.

The bridge has an overall length of 1,650 ft and consists of 11 units supported by piers 15 ft thick in the direction of traffic and spaced at 150-ft centres. Each unit consists of a roadway section supported by vertical cross-walls resting on a barrel-type parabolic arch.

The specifications required separate centering for all the arches so as to prevent unbalanced loading of the piers. Each arch centering unit consisted of a deck system supported by fifteen three-post trestles resting on the spillway crest, partly on the concrete and partly on the spillway gates in their lowered position. To keep the deck adjusted to a theoretical curve, twelve sets of hardwood wedges were inserted between the cap of each trestle and the sill of the joist above it. The centering was left in place for at least thirty days after all concrete had been placed in the arches. Construction of the superstructure was not permitted until the arches were allowed to take their own



Fig. 1.—Spillway Bridge from Downstream side

weight by simultaneously lowering the centering of all arches for uniform loading of the piers. To reduce unbalanced loads on the centering during construction of the arches, and on the arches during construction of the superstructure, each unit was erected in segments in the order shown in Fig. 2. Accordingly, the concrete was placed in corresponding segments of all units as nearly at the same time as was practicable.

The contractor was required to place the concrete in the arches under certain

temperature conditions, except that concrete could be placed in segments Nos. 1 and 2 as soon as the forms were ready. Concrete was permitted to be placed in the No. 3 segments if the temperature of the concrete in segments 1 and 2 was 70 deg F or less, and in the closure segments Nos. 4 if the concrete temperature in segments Nos. 1, 2 and 3 was 70 deg F or less. Temperature readings of previously placed concrete were secured from thermometers placed in wells in the bosses for the cross-walls. Cooling of the con-

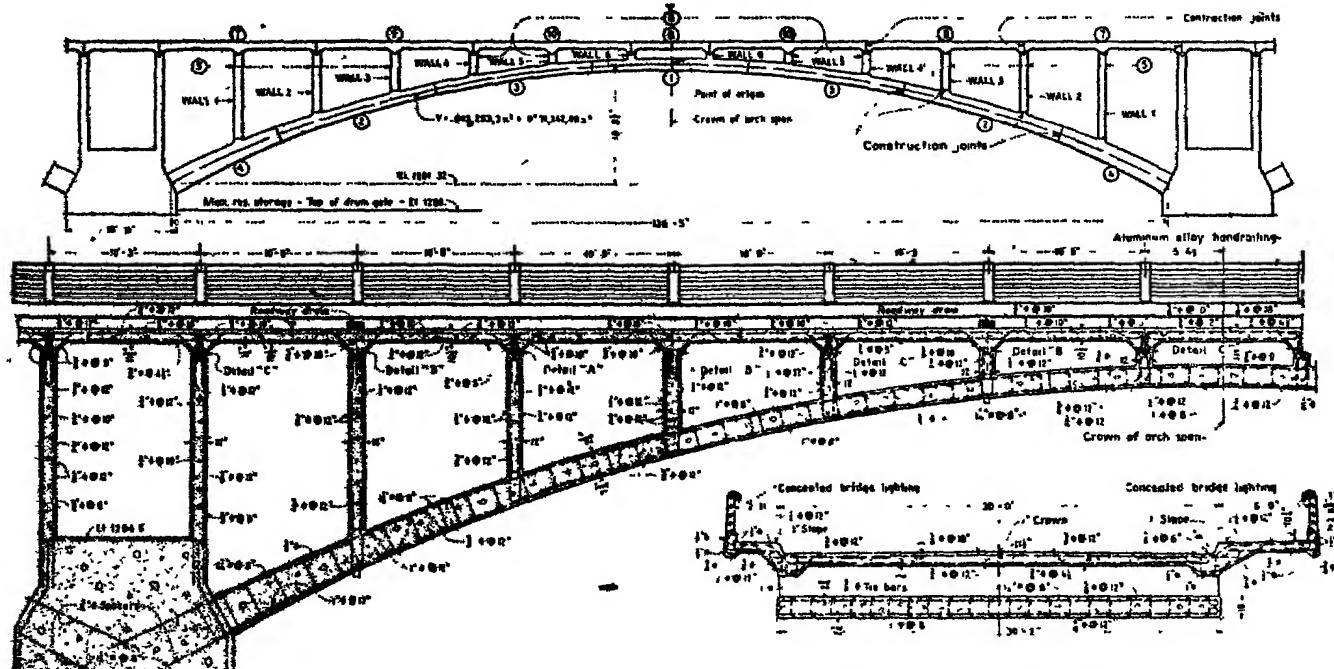


Fig. 2 (top).—Diagram showing Sequence of Construction. Fig. 3 (bottom).—Section of Half Span at Centre-line.

crete was effectively accomplished by fog spraying with river water.

Each span was designed to have a 1-in. camber from the pier to the middle of the span at a mean temperature of 50 deg. F. If at the time of construction the mean temperature varied from 50 deg. F., the elevations for the roadway were determined by applying a corrected ordinate of elevation, calculated from a parabolic distribution in which the major axis would be equal to the length of the span, and the half minor axis would equal $\frac{1}{3}$ in. for a 50 deg. F. rise or fall from the 50 deg. F. mean temperature. The temperature of the structure was assumed to be equal to the mean air temperature of the three preceding days.

The Piers

The piers between the drum gates for the spillway control provided ideal supports for the bridge spans. Although a float-well and stair-well were installed in each pier, there was sufficient reinforcement near the surfaces of the piers and around each well to make the piers fully capable of supporting the bridge for any

movements rather than as arch ribs in order to afford greater lateral rigidity against earthquake shocks.

The reinforcement of the arches consists of longitudinal bars at 8-in. centres on both faces, and transverse bars at 12-in. centres on both faces; the two layers are tied with a $\frac{1}{2}$ -in. round tie-bar for every $\frac{1}{4}$ sq ft of area. The longitudinal reinforcement in the extrados is $1\frac{1}{2}$ -in. square bars at both crown and abutment, reducing to 1-in. near the quarter-point. The longitudinal reinforcement in the intrados consists of 1-in. round bars from the crown to about the haunch, where $1\frac{1}{2}$ -in. square bars are used. The reinforcement bars at the abutment intrados are $1\frac{1}{2}$ in. square. The transverse reinforcement consists of $\frac{1}{2}$ -in. round bars in both faces for the entire arch except near the abutments, where 1-in. round bars are used.

Stresses were computed for the effects of (1) an H₂₀-S16 highway loading, (2) earthquake shocks, (3) differential water load on a pier, and (4) heating of pier-plates for de-icing purposes.

(1) An H₂₀-S16 load is a relatively

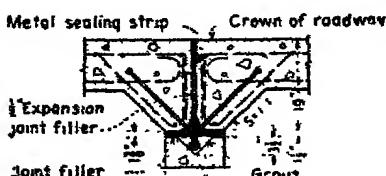


Fig. 5—Detail at A (Fig. 3).

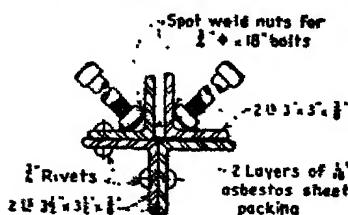


Fig. 6—Bearing for Detail shown in Fig. 5.

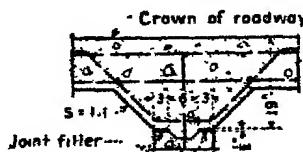


Fig. 7—Detail at B (Fig. 3).

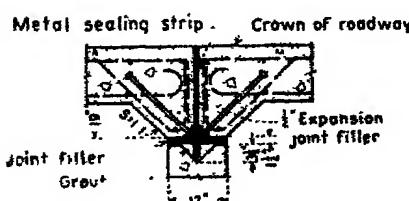


Fig. 8—Detail at C (Fig. 3).

non-symmetrical loading due to traffic. The reinforcement is well embedded in the mass of the dam and serves to provide lateral stability for the bridge in the case of a horizontal earthquake shock.

The Arches

Each arch barrel supporting the roadway has a width of 30 ft 2 in., a clear span of 135 ft., and a rise of 16 ft 6 1/2 in. The thickness varies from 18 in. at the crown to 36 in. at the springing line. Because of the position of the bridge at the top of the maximum section of the dam (Fig. 3) at about 550 ft above the rock foundation surface it was considered advisable to construct the arches as rigid barrel seg-

ments rather than as arch ribs in order to afford greater lateral rigidity against earthquake shocks.

The reinforcement of the arches consists of longitudinal bars at 8-in. centres on both faces, and transverse bars at 12-in. centres on both faces; the two layers are tied with a $\frac{1}{2}$ -in. round tie-bar for every $\frac{1}{4}$ sq ft of area. The longitudinal reinforcement in the extrados is $1\frac{1}{2}$ -in. square bars at both crown and abutment, reducing to 1-in. near the quarter-point. The longitudinal reinforcement in the intrados consists of 1-in. round bars from the crown to about the haunch, where $1\frac{1}{2}$ -in. square bars are used. The reinforcement bars at the abutment intrados are $1\frac{1}{2}$ in. square. The transverse reinforcement consists of $\frac{1}{2}$ -in. round bars in both faces for the entire arch except near the abutments, where 1-in. round bars are used.

Stresses were computed for the effects of (1) an H₂₀-S16 highway loading, (2) earthquake shocks, (3) differential water load on a pier, and (4) heating of pier-plates for de-icing purposes.

(1) An H₂₀-S16 load is a relatively

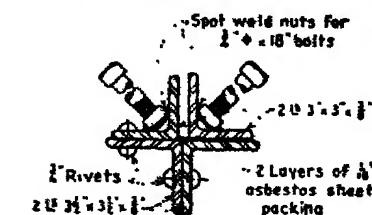


Fig. 6—Bearing for Detail shown in Fig. 5.

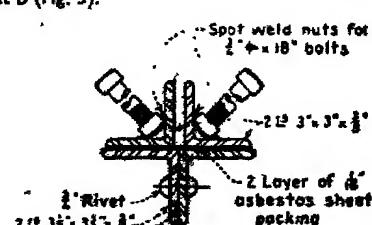


Fig. 9—Bearing for Detail shown in Fig. 8.

a difference in water pressure on the sides of the piers adjacent to the lowered gate. The unbalanced loading thus created will cause the piers to deflect and disturb the stress distribution throughout the arches.

(4) Stress concentrations caused by heating the pier-plates is a condition that might arise during winter operation of the gates. The pier-plates are constructed of segments of cast iron embedded in the sides of the piers at the ends of the spillway gates in their raised position (Fig. 10) and provide a durable plane surface at the ends of the gates for sealing purposes. A stress disturbance in the arches will arise if the piers are deflected due to heating these pier-plates for de-icing the ends of a gate so that it may be lowered. For the purpose of a stress investigation it was assumed that, with water in the reservoir to the top of the gates and with one or more gates open, a severe loading could develop on the piers between the open and closed bays if it were necessary to heat the pier plates at the ends of the raised gates. This assumption combines the effects of pier-plate heating with the effects of a differential water load on the pier to produce a severe stress concentration in the arch barrels supported by the pier.

Superstructure

The superstructure is composed of all component parts above the arch barrel and consists of the roadway section, footpaths, railings and the supporting cross-walls between the deck and the arch.

The roadway deck slab is 30 ft wide between kerbs and has a thickness along the centre-line of $10\frac{1}{2}$ in. for the two-span continuous segments and $11\frac{1}{2}$ in. for the simple spans at the pier and central segments (Fig. 3). A 1-in. crown is provided for drainage. Besides being supported at the cross-walls the slab is also supported by a reinforced concrete spandrel beam at its upstream and downstream edge. (Fig. 4) These spandrel beams also serve to support the cantilevered footpaths that flank the bridge on each side. The footpath on the upstream side is 2 ft. 11 in. wide and on the downstream side 6 ft wide. Along the edge of each footpath will be a horizontal bar guard railing, the top bar of which will house an indirect lighting system. The railing is designed to withstand the shocks of uncontrolled vehicles.

As a means of minimizing the effects of contraction and expansion due to temperature changes and the effects of strains due to arch flexure, the deck slab was articulated into longitudinal lengths of $10\frac{1}{2}$ ft. and $21\frac{1}{2}$ ft. by transverse joints. The joints also serve to prevent increased concentrations of load on the arches. Joints were provided for three different sets of conditions.

Figs. 5 and 6 illustrate a condition wherein one end of a deck slab segment is rigidly fixed to its support and the adjoining end of an adjacent segment is free to slide. This joint was devised to relieve any horizontal thrust that might develop against cross-wall No. 1 (Figs. 2 and 3); otherwise it would have been necessary to make the wall thicker in order to keep the stresses within working limits. The bottom bearing elements of the joint consists

of two $3\frac{1}{2}$ -in. by $3\frac{1}{2}$ -in. by $\frac{1}{2}$ -in. angles riveted together and grouted into the supporting cross-wall. The top bearing elements of the joint consist of two 3-in. by 3-in. by $\frac{1}{2}$ -in. angles, one of which is riveted to the bottom bearing element and the other separated from the bottom

bearing element by two $\frac{1}{8}$ -in sheets of asbestos packing. One of each of the upper bearing angles is anchored to one of the adjoining slabs by $\frac{1}{4}$ -in bolts 18 in long screwed into square nuts welded to the angle-iron at 18-in centres and then embedded in the concrete of the slab.

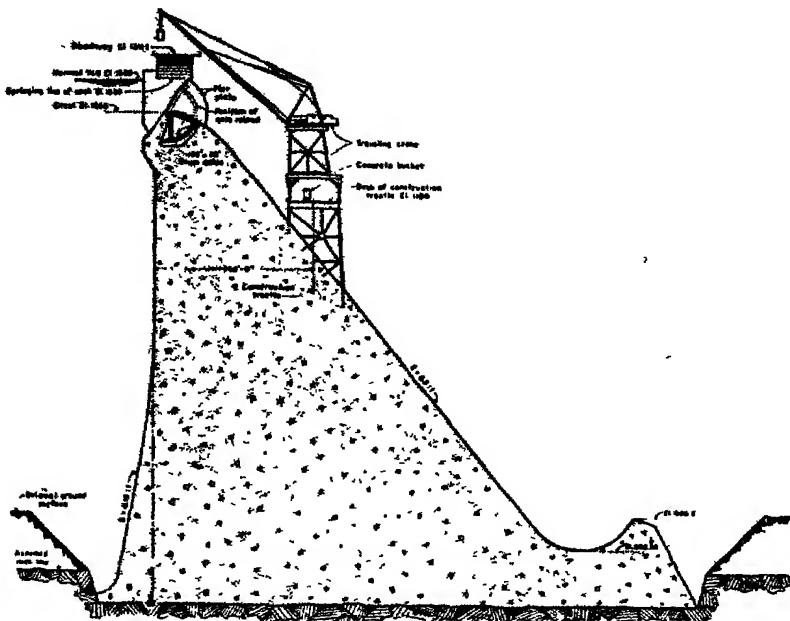


Fig. 10.—Method of Placing Concrete.

(Continued from page 112)



TRANSITION SECTION connecting circular test cell with rectangular chamber requires special forms, two of which are shown here in position for concreting lower third of cell.

two ends opening into rectangular intake and exhaust chambers. A photograph shows framework for one of these transition sections. In addition to these structural features, numerous openings into the control rooms, fittings for engine blocks and tramways, a large amount of piping and electrical conduit and some complicated reinforcing added to the

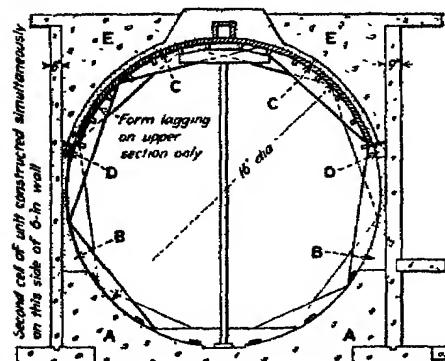
difficulties of the job

Ingenuity in construction methods was one of the deciding factors in the award of an Army-Navy "E" to the joint contractors, Long Construction Co., Kansas City, Mo., and Turner Construction Co., New York, operating as Long-Turner, builders of the plant for the Defense Plant Corp. John C. Long was

Fig. 7 illustrates a joint between a two-span continuous deck segment and its centre support. This joint was made by forming a recess along the centre line of the top of the supporting cross wall and then keying the deck concrete into it. The concrete adjacent to the sides of the recess was separated from the deck by $\frac{1}{2}$ -in. thick strips of joint filler. This joint was designed to permit some rocker action, but no horizontal movement other than that due to the flexibility of the support.

Figs. 8 and 9 show a joint designed to permit horizontal movement but no rotation. In this joint the lower bearing plate comprises two 3½-in by 3½-in by ¾-in angles, riveted together and grouted into the supported cross-wall. The upper bearing plates consist of two 3-in by 3-in by ¾-in angles, each anchored to the adjoining ends of adjacent deck segments. Anchorage is effected by ¾-in bolts 18 in long screwed into square nuts welded to the angles at 18-in centres and then embedded in the deck concrete. The plates are separated by two layers of ¼-in asbestos-sheet packing.

The joint between the ends of the deck slab segments is $\frac{1}{4}$ -in wide and is filled with an expansion joint filler. Across this joint and about 6-in below the surface is a metal sealing strip, welded to the reinforcement, to prevent moisture penetration to the angles in the joint. Each joint is continuous across the deck slab and both footpaths.—(*With acknowledgments to "Concrete and Constructional Engineering"*)



SEQUENCE OF OPERATIONS in constructing 16-ft-dia. cell walls for these steps, (1) Place dry concrete for section A, (2) erect forms; (3) Gunite section B from inside; (4) Gunite section C from above; (5) Gunite section D from inside; (6) place concrete in section E Slot at Section D is left open temporarily to dispose of material which may collect in upper portion during Guniting of section C

project manager, and the assistant project managers were Robert Long and M. Herschel Parsons, the latter representing the Turner Construction Co. Albert Kahn Associated Architects and Engineers, Inc., Detroit, designed the test cells and all other buildings of the plant.—(With acknowledgments to "Construction Methods")

LARGER DIAMETER TEST CELLS

Concreted to $\frac{1}{4}$ in. Tolerance

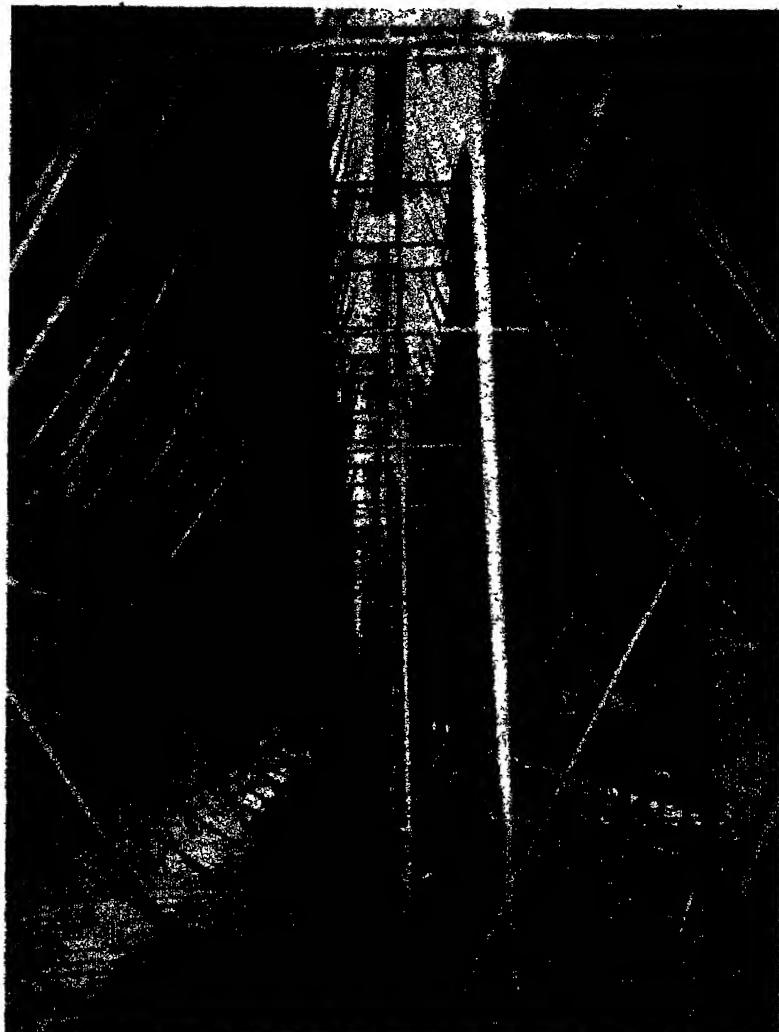
FORMING and Concreting Methods designed to assure accurate construction of reinforced-concrete test cells 16-ft and 24-ft in diameter at the Pratt & Whitney aircraft engine plant Kansas City, Mo., enabled Long-Turner contractor to complete the circular cells within the close tolerance of $\frac{1}{4}$ in. allowed by specifications. The concrete cells were built up in successive lifts from the bottom to the top with horizontal construction joints between the sections. Construction involved placement of 1,232 to 2,700 cu yd of concrete in units consisting of two test cells and one control room observation gallery per unit.

Different methods were employed for the two sizes of cells. As the first step in constructing the 16-ft dia unit vertical reinforced-concrete walls were built at the two sides of each cell, using slip forms to conserve lumber and obtain maximum progress with least use of limited working space. These walls were 9 in. and 6 in. thick, as indicated by an accompanying drawing.

To start the test cell itself dry-mixed concrete was placed for the bottom lift, comprising about one-fourth of the circular section and the invert was shaped to the 16-ft diameter by use of a template. On the completed invert, the contractor erected built-up wooden rings which were lagged only on the upper third to provide forms for supporting concrete.

Side-wall sections of the test cell next were constructed by shooting pneumatically applied Gunite against the previously completed vertical walls in the area between the invert and the top form. Operators standing inside the cell applied this concrete from nozzles and shaped it in conformity with the wooden form rings which served as templates. A slot, indicated on the drawing, was left at the top of the side-wall sections, below the form lagging, to facilitate the next operation.

To permit accurate control of the shape of the barrel, the concreting of the top section was carried out in stages. Placing the entire mass of concrete in one operation would have caused some form settlement and trouble with shrinkage. As a means of eliminating these difficulties, a layer of Gunite first was applied from above on top of the forms, as noted on the drawing. This layer was 3 in. thick except at the crown, where it increased to 12-in. depth. The open slot at the bottom of the forms provided a ready exit for rebounds and any other deleterious material which collected while the concrete was being applied. The slot then was filled by Guniting from inside the forms. As the final step, the remainder of the upper part of the cell was concreted by ordinary methods. The weight of this concrete had a tendency to close the construction joints



FORMS FOR LOWER THIRD of two 24-ft.-dia test cells are tied down by anchor rods to concrete pads previously placed. Each test cell construction unit comprises two cells and a control room observation gallery.

Large Cells

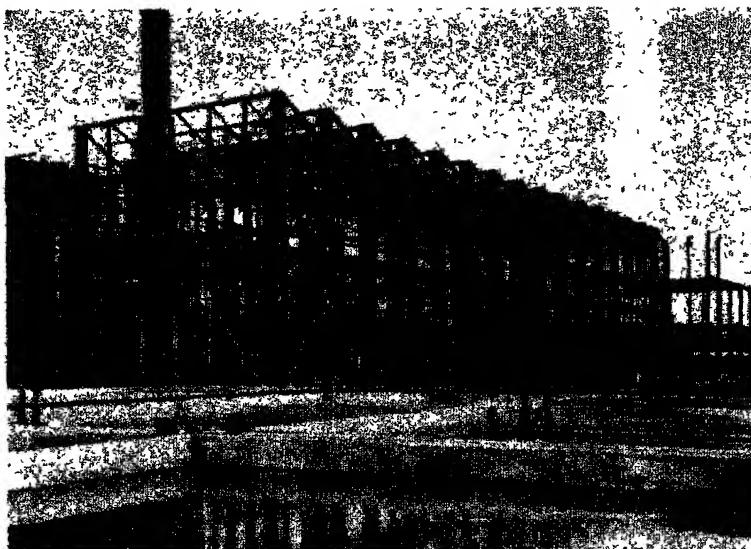
For the 24-ft.-dia cells, a different method of forming and concreting was necessary. No vertical walls were included in the design of these cells. Because the 24-ft. diameter precluded accurate shaping of the invert by template, concrete for the bottom third was placed in forms which were tied down by anchor bolts and rods to concrete pads previously placed.

Separate sets of forms were used for each of the three stages of construction of the 24-ft barrels. After the invert had been concreted, the bottom forms were removed, and the side forms were set for the middle third. These forms, in turn were stripped before top forms were

placed for concreting the final third of the cells. Construction joints were formed at recesses located about one-third and two-thirds up the side of the cell walls. The recesses accommodate track for retractable platforms employed in setting engines to be tested. Use of separate sets of forms eliminated the danger of cumulative settlement which might have occurred in barrel forms. In addition, use of an individual set for each third of the cell simplified the form-work and provided more working space.

All forms were well built, strongly braced and securely bolted. Each circular barrel has transition sections at the

(Concluded on page 111)



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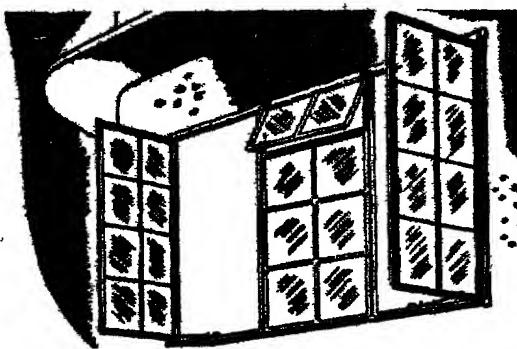


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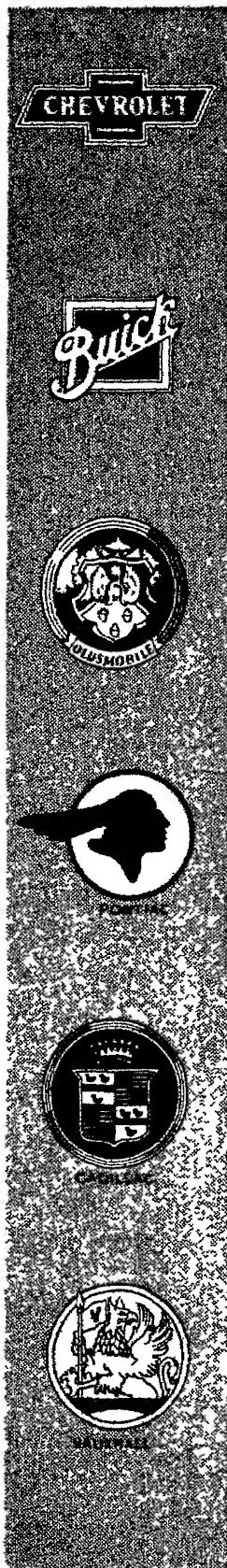


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AMRITSAR	HASAN ABDAL
ARIFWALA	ISAKHEL
ATAR	INJRA
BADAMI RAGH	JAGRAON
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BANNI	JANDIALA
BARIWALA	JANIWALA
BATALA	JARANWALA
BEGOWAL GHARTAL	JHANG MAGHIANA
BEAS	JHELM
BHAGTANWALA	JOGINDERNAGAR
BHAKKAR	JULLUNDER CITY &
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BHATINDA	JUTOGH
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CHAKWAL	KAMOKA
CHAWINDA	KANGANPUR
CHANANWALA	KANGRA
CHANGAMANGA	KAPLUTHALA
CHENAB WEST	KARTARPUR
PANK	KAROR
CHHEHARTA	KASALI
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DOKHLA	LYALLPUR
DUNGA BUNOA	MACLEOD GUNJ
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FEROZEPUR CITY	MALOUD
A CANTT	MALYAN SHANKOT
GAHSHANKAR	MANDI BAHAUDDIN
GAKHAR	MANGE
GAZIGA	MARI BALOCHAN
GHAGGAR	MANDI BUREWALA
GEDDARBABA	MANDI STATE
GORIANA	MANGWAL
GORAYA	MARDAS
GUJARKHAN	MAMU XANJAN
GOHINDGARH	MAUR
GOJRA	MAINWALLI
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MARANO
NAROWAL
NAWANSHAHR
DOABA
NOWSKERA
NURKOT
NURMAHAL
NUEPORE ROAD
NAGROTA
OKARA
PALAMPUR
PARACHINAR (*Viz.*
Tsdi)
PABSR
PATANKOT
PAKPTATTAN
PATTI
PINDIGHEB
PATTOKI
PESHAWAR
PHAGWARA
PHILLAUN
PHULERWAN
PIRMALAH
PIND DADAN KHA
PIPLAN
QADIAN
QILLA SHEIKBU-
PURA
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RAIKOT (*R. S.*
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RAHWANI
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SANGLA HILL
SILLANWALLI
SAKAI ALAMGIE
SAROOGHDA
SARNA
SATNAUR BADE-
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SHAH ALAM
SHAHADA
SHARAKPUR
(*R. S. Shaheed*)
SHAHPORE SADAB
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SIHLA
SIMLA
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SOLOK
SUJKHO
SULTANPUR LODHI
SUKHEEK
SEWAGAR
S. S. Rawalpindi or
Ramgarhia
TALAGANG (*B. S.*
CHHETRI)
TALWANDI
TARN TARAH
TANDA PIRMAR
TANDIANWALA
TANK

TAXILA
THERI SANSI
TEHSIL SHAKAR
GARH
THABALKE
WAL

TOBA TEK SINGH
V KHARI
VERKA
WAIZIRABAD
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WASAWEWALA

NEW DELHI AREA

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ACHMALDA	KAITHAL
AGASA	KASHIPUR
AHIMAKPUR	KASIMPUR KHERI
AHRAURA ROAD	KOSI KALAN
AJODHIA	KOTDWARA
AJODHYA	KURUKSHETRA
AKKAPUR	LEHAGAGA
ALIGANJ	LHAKSAR
BAKRA	LOHARU
BARNALA	MANDI DHANAURO
BAGHPAT ROAD	MADLAUDA
BAH (R 8 BULANDSHAH)	MANSURPUR
BAMADURGARH	MEEBUT
BAHJOI	MILAK
BARETA	MORADABAD
BAKSIRTHATHPUR	MUNDHLANA
BAHAMABAD	MURADNAGAR
BHIWANI	MURSAN
BUCHCHU	MUTTRA
BALLABGARH	MUZZAFFARNAGAR
BAURAT	NAJJABAD
BUDHLADA	NAGARIA SADAT
BULANDSHAH	NAGINA
BUJNOH	NABA
BRINDABAN	NANAUTA
CHANDAUSI	NARELA
CHANDPUR SIAU	NARWANA
CHOLA	PALWAL
DADRI	PANIPAT
DALMIA-DADRI	PATIALA
DIBAI	PILKHUWA
DEHRA DUN	RAIWALA
DELHI SHANDRA	RAJA-KA-SAHAS-
DEOBAND	PUR
DAMLAUR	RAJGHAT-NABORA
DAURELA	RAJPURA
DHAMPUR	RAMAN
DHANARI	RAMNAGAR
DOIWALA	RAMPUR
ETIADPUR	RAMPUR MANHYA
FARIDBAD	RAN
FEROZABAD	RAMPURA PHUL
GANAUR	RAYA
GANGOH	REWARI
GARHMUKHTESAR	ROHTAK
GHAZIABAD	ROORKEE
GHRAUNDA	ROHINKESH
GOT	SAFIDON
GOHANA	SAHARANPUE
GURGAON	SAMPLA
GULAOOTI	SANGERUR
HALDAUR	SABNI
HANSI	SURAN
HARDWAR	SAMBAL KH
HAFUR	SAMBHAL HATIM
HATHRAS	SARAI
HISSAR	SARSAWA
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JAGDHRI	SHIKHOBAD
JAHHAL	SHAHABAD MAR-
JALESBAR ROAD	KANDA
JAWALAPUR	SHAMILI
JIND CITY	SIRSA
JULANA	SONPAT
KALANWALI	SIMBHAPOLI
KANTH	TAPA
KANDHLA	TAPRI
KAURABA	THANA BEHAWAN
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	UGHANA
	UKLANA
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ACHALGANJ	ALLAHABAD
ACHMALDA	AMETHI
AGASA	AMOONI
AHIMAKPUR	ANHINI
AHRAURA ROAD	ANUPPUR
AJODHIA	ASOPA
AJODHYA	ASOPUR
AKKAPUR	ATARI
ALIGANJ	KURVIA

CAWNPORÉ AREA

ACHALGANJ	ALLAHABAD	GURHAIKANJ
ACHRAHLDA	AMETHI	GURSAHAIKANJ
AGSAILI	AMOUDI	HAIDARGARH
AHIMAKPUR	ANGRI	HALDWANI
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AKKAEXPUR	ATARI	MARNANGANJ
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		HAMPALPUR

Cawnpore Area (Contd.)

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JANG
JAKHANIA
JALALPUR
JANGHAI JN.
JANGJANI
JAWAL ROAD
JAWANTHAGAR
JAUNPUR
JAWATAPUR
JHANSI
JHURI
JABRAI
JACHELA GHAT
JACHHWA ROAD
JADIPUR
JAIMGANJ
JALPI
KAMALGANJ
KAMALPUR
KANAUJ
KANCHABJI
KARARI
KARENJI
KARWI
KASGanj
KASHI
KATHGODAM
KATHKULYAN
KATKA
KAWAPUR
KEDARPUR
KERAKAT
KHADA
KHASA
KHALLABAD
KHATENA
KHETTA SARAI
KHOBASAN ROAD
KICHLA
KIDWIDAPUR
KHONDAUR
KHON ROAD
KOPAGAJ
KUNCH
KUNRAGHAT
KUSMHI
LACHHIPUR
LAKHIMPUR KHERI
LAKSHMIGANJ
LALGANJ
LALETPUR
LAR ROAD
LUCKNOW
MADHOGANJ

MADHOOSINGH
MADMUDABAD
MARORI
MAROLI
MAHTUK
MAHPUR
MACHANDPUR
MACHHAD
MAIJPUR
MAJLAWAN
MANAURI
MANDAH ROAD
MANKAPUR
MANFUR NAGARIA
MARBHRA
MARIAHU
MASKHAWA
MAU AIMA
MAU RATH
MEANJAN
MAURAMIPUR
MEJA ROAD
MERANPUR KATRA
MIRZAPUR
MIRZIKH TIRATH
MOGHAL SARAI
MOTH
MUSAMMADABAD
GOHNA
MUNDKEWA
MURAFIKHARA
NAGARIA SADAT
NAIPALGUNJ ROAD
NANDGUNJ
NAMPARA
NAUTANWA
NAWBUNGO
GONDA
NEKKABORI
NOVGARH
ORAI
OROHN
PACHPERWA
PADRAUNA
FABRIAWAN
PARTABGABH
PATIALA-ON-
GANGER
PAYAGPUR
PEPPEGANJ
PHAPHUND
PHABENDA
PHARIHA
PHEPHNA
PHULPUR

PIFRANCH
PITAMBEPUR
PILIBHIT
PUKHRAYAN
PUNCH
PUBANPUR
RAGAUL
RAGHURAJ SINGH
RAJ BARILL
RAJA KA RAMPUR
RAJA TALAB
RAJAWARI
RAJKHOLA
RANI-KI-SARAI
RASULI
RASRA
RAZULABAD
REOTI
REKHA ROAD

RISIA
RUDAIN
RUDAULI
RURA
SAADAT
SAFDAR GANJ
SAFIPUR
SAHATWAB
SAHAWAR TOWN
SAHJANWA
SAIDPUR KHITR
SAIYEDHABA
SAXALDHA
SALIMPUR
SANDILA
SARAIMIR
SARDARNAGAR
SARJU
SHAHGANJ

SHAHGARH
SHAHJAHANPUR
SHAMBHABAD
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SHIVPUR
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SHRI KRISHNA
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SIKANDARPUR
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SIWA, BAZAR
SITAPUR
SOHON
SULTAKPUR
SURAIHANPUR
SURAIWAN
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TAHSIL FATEHPUR
TAKIA
TAMKOHI ROAD
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TANDA
TALAON
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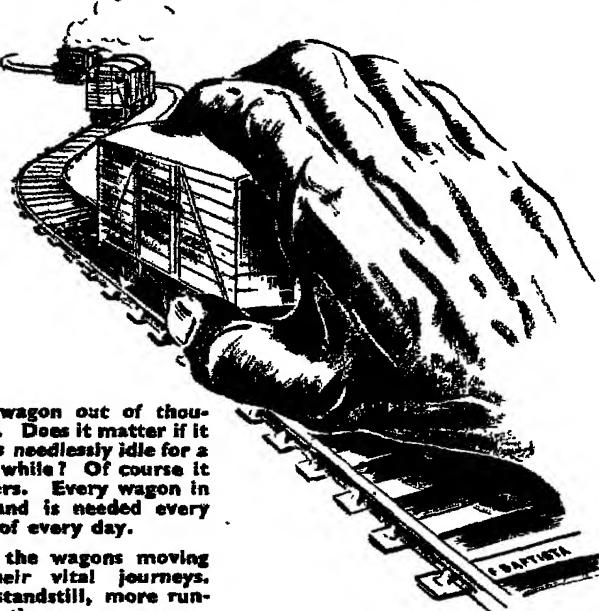
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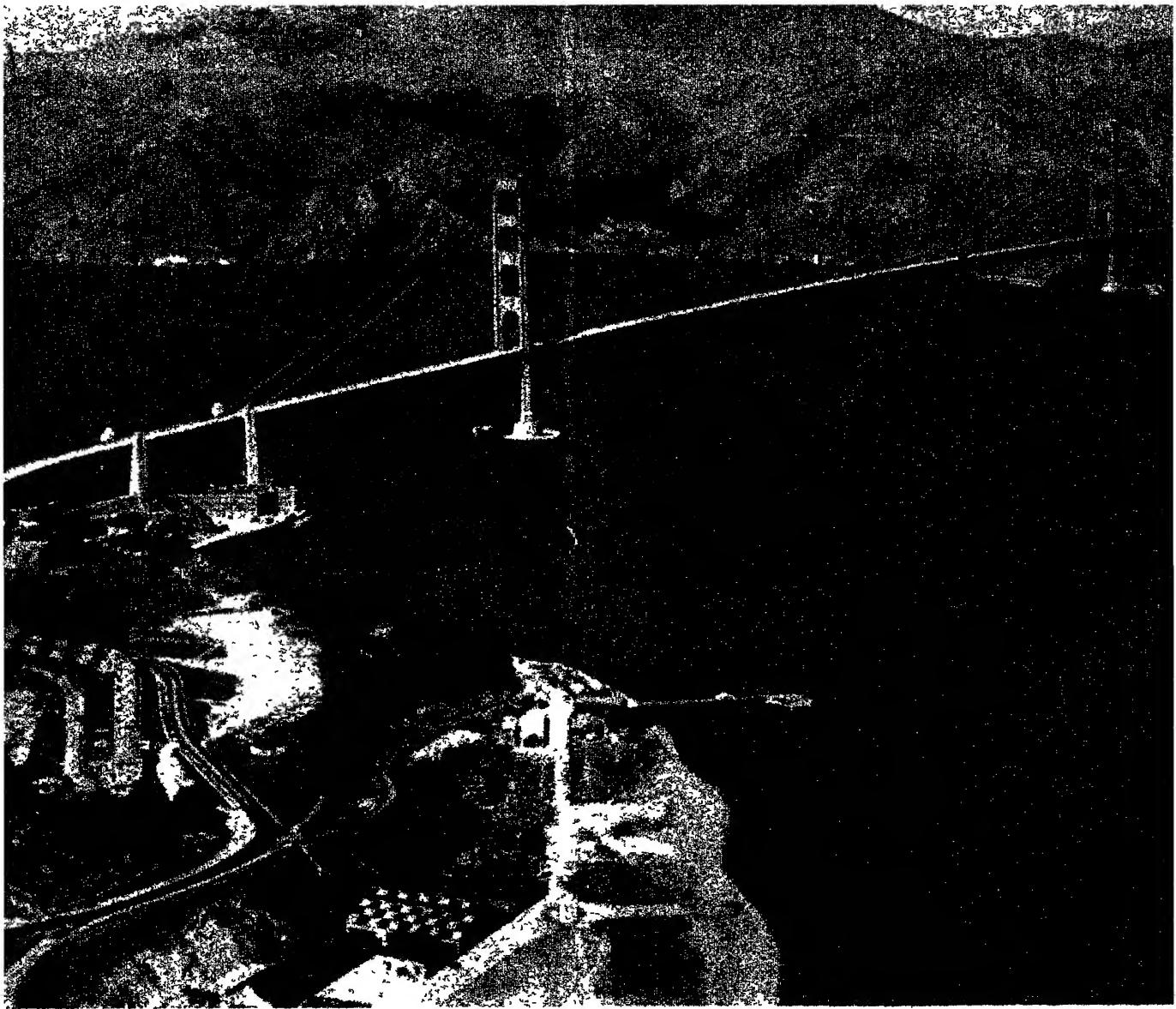


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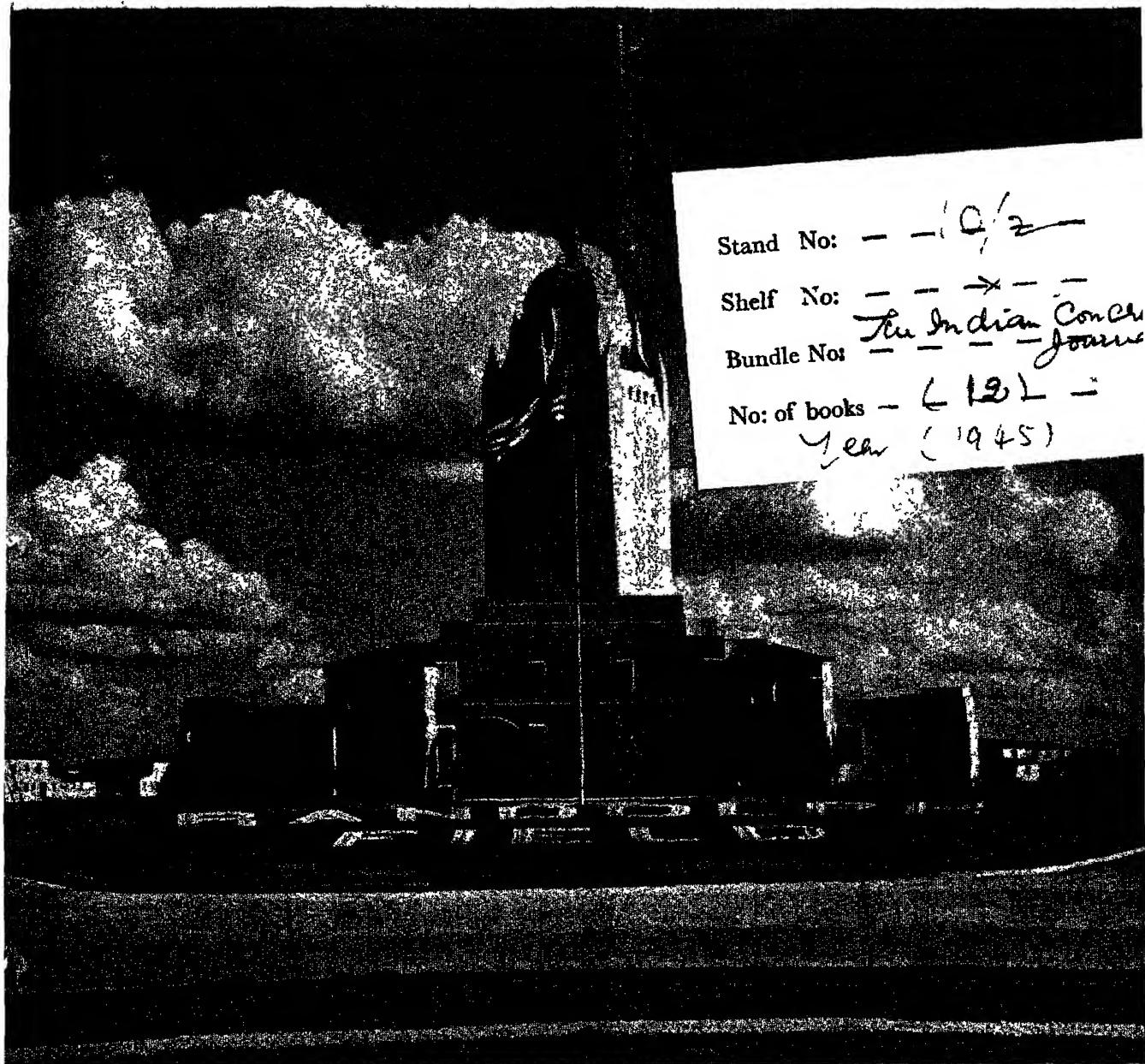
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INDIAN CONCRETE JOURNAL

VOLUME XIX

AUGUST 1945

NUMBER 8



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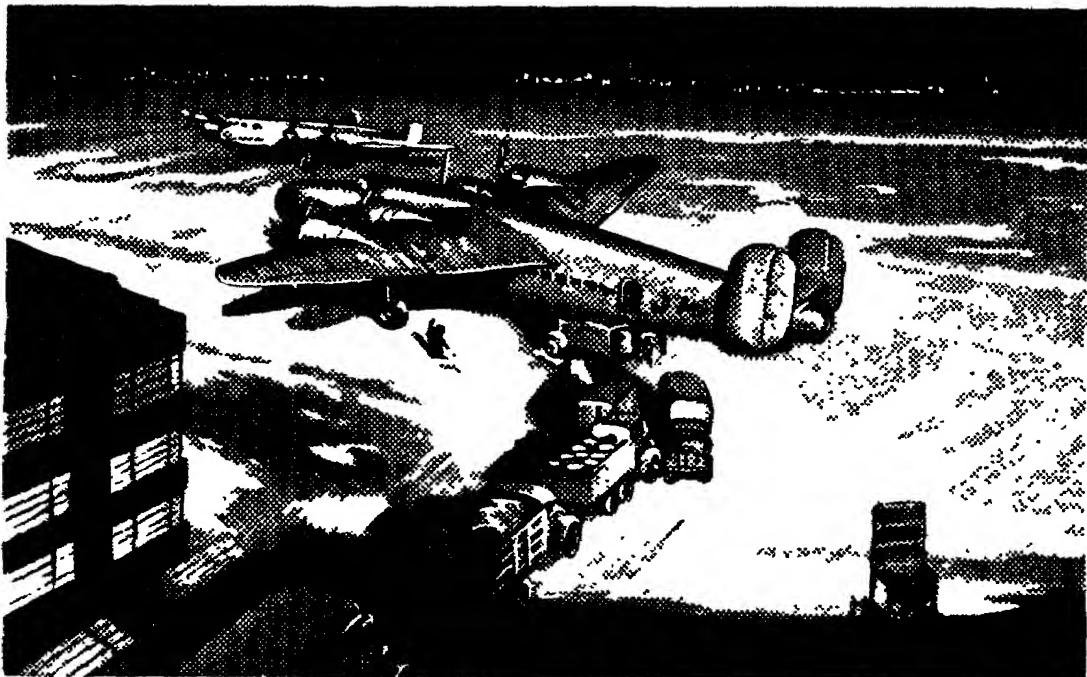
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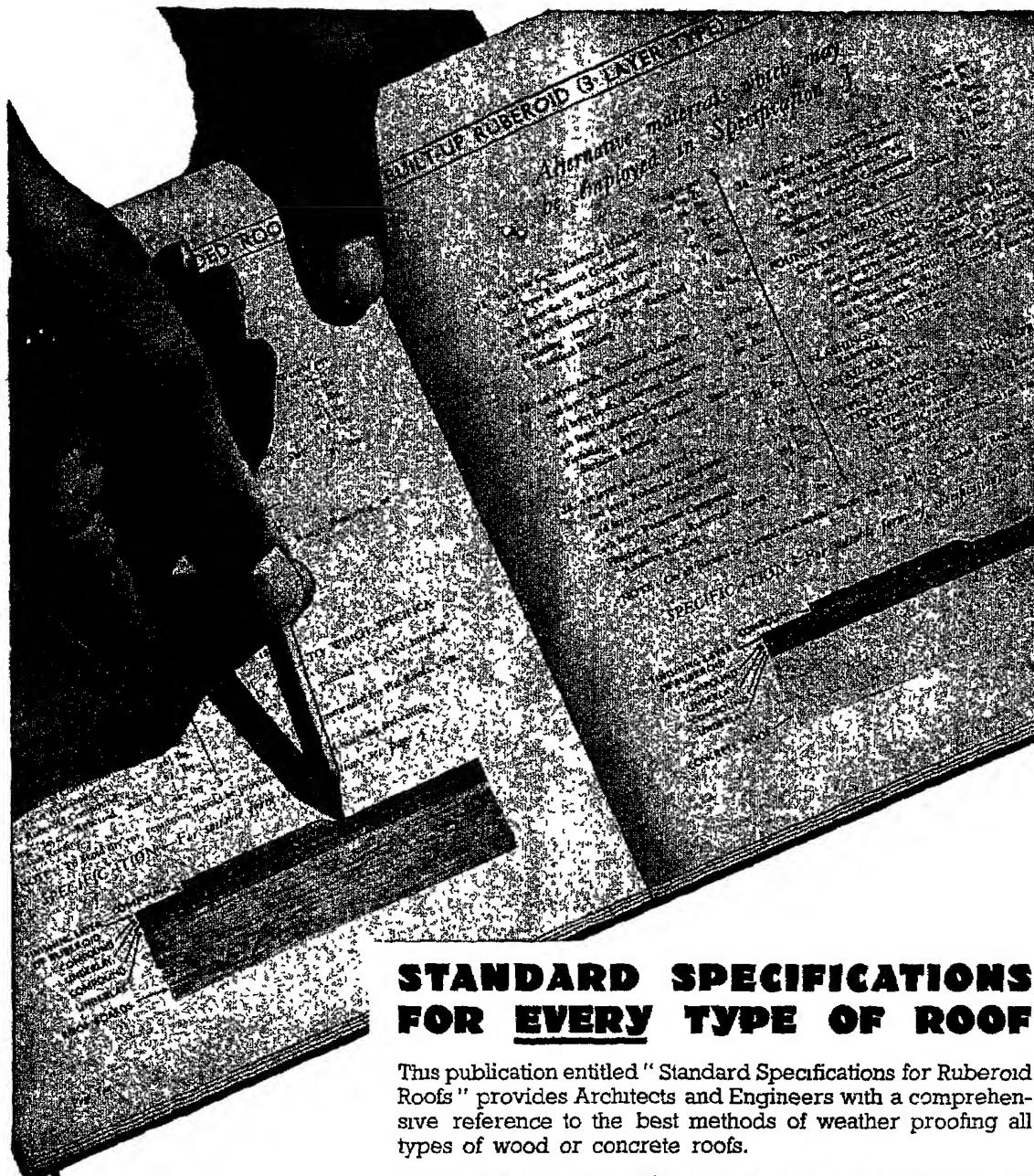
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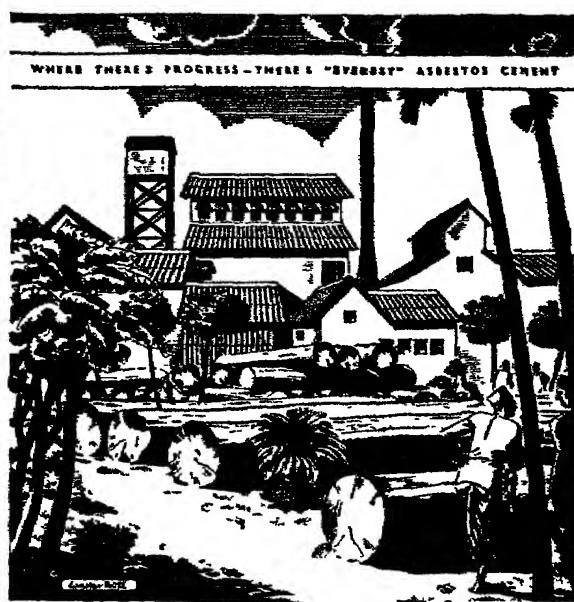
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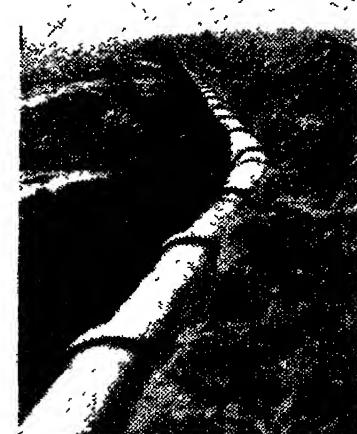
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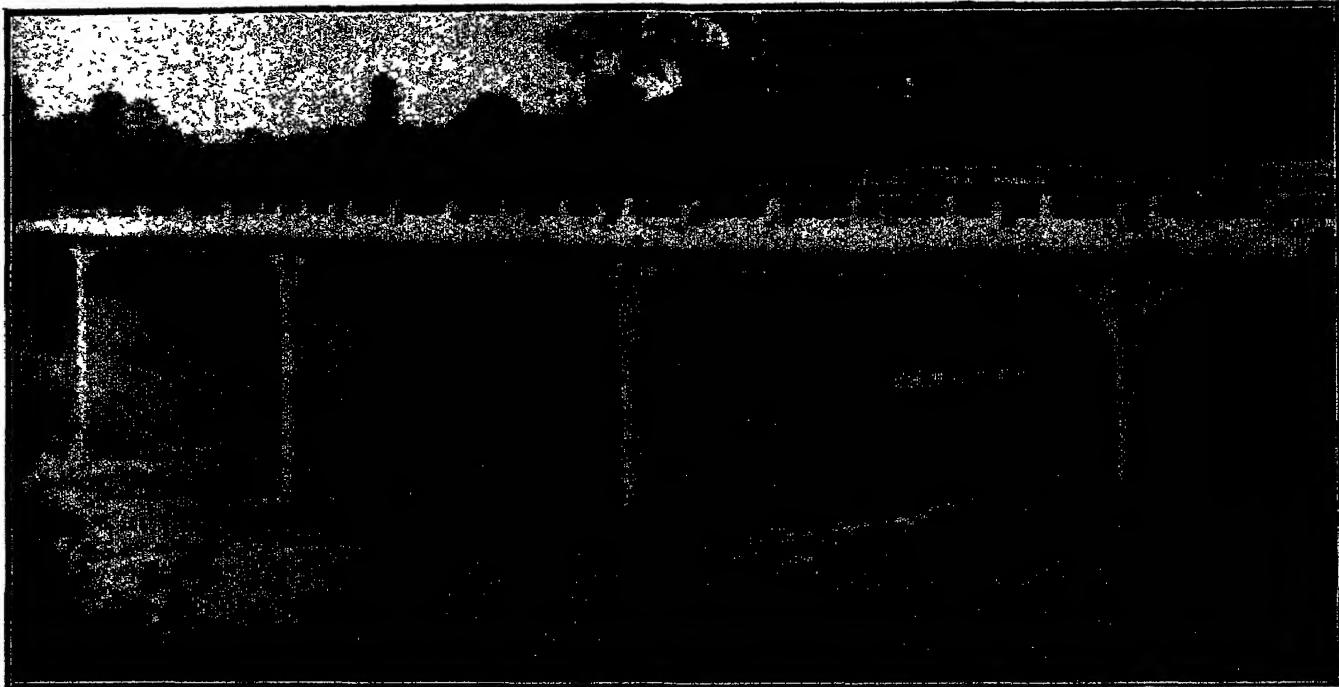
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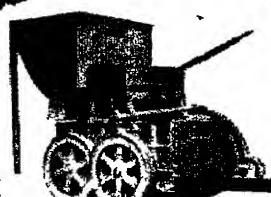
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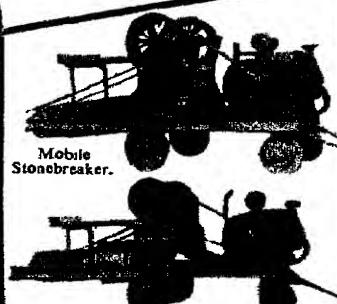


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THE INDIAN CONCRETE JOURNAL

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EDITORIAL NEWS & NOTES



ENGLISH ROADS AND CONGESTION

THERE is considerable fear, as expressed in periodicals reaching this country, that the roads of England, already dangerously congested before the war, will become almost impossible for the traffic that is likely to descend upon them when wartime restrictions are removed.

Not only are most of them quite unfit to receive the coming mass of traffic of every kind, but the previous death and accident roll is bound to go up again by leaps and bounds. It will probably exceed even the figures that were becoming common before the war and which people were becoming accustomed to.

The remedy is by no means obvious but tinkering with the subject should be avoided. Only bold and drastic steps will be of any real use. These bold and drastic steps will necessarily cost a great deal of money spent on amenities such as pavements, cycle tracks, crossovers and so forth. In addition, entirely new arterial roads designed for fast long distance traffic will be necessary.

How are we, in India, proposing to meet these dangers and difficulties which will assuredly come upon us when motor traffic increases as it is practically bound to do?

One thing we must do and that is to allow for future expansion now, before it is too late, and we must press for legislation to prevent ribbon development, the curse that has already overtaken so many countries. There must be ample room for pedestrians in and near towns, and cyclists should be catered for on all roads. As the bullock cart is likely to be with us in some form or another for at least another 100 years it must also be catered for.

All this will cost much money and it is obviously not possible to do everything at once but every road user will surely hope that the designers of our post-war roads will not allow their judgment to be influenced by any short-sighted policies and where it is impossible to build roads as they ought to be built, at least let us reserve enough room for the essential needs of the future BEFORE IT IS TOO LATE.

SOME NOTES ON EFFLORESCENCE

TECHNOLOGIC Paper No. 349, of the United States Bureau of Standards, reporting on an investigation of the physical properties of limestone, states.—

"Efflorescence is a growth of crystals on the surface and in the pores of the masonry where a salt solution evaporates. The solvent carrying the salt is probably always water. The source of the salt may be varied, but in most cases it is leached from the masonry walls by water as it slowly percolates through the pores."

"No building material is entirely free from water-soluble salts and the small amounts of such which usually appear in chemical analyses as a few tenths of one per cent, are sufficient when leached out and concentrated at same point on the surface to cause efflorescence."

It will be noted that all masonry materials are subject to occurrences of efflorescence. The amount and character of the deposits vary widely, apparently depending on the nature of the soluble materials and atmospheric conditions. The deposit may or may not be soluble. In some cases, therefore, it disappears by being washed off by rain.

In the case of concrete, mortar, stucco, cast stone or concrete masonry, the hydrated cement contains some calcium hydroxide (soluble) as an inevitable product of the reaction between cement or lime and water. When this soluble material is brought to the surface by water it combines with carbon dioxide in the air, forming calcium carbonate (very slightly soluble) which appears as a whitish deposit known as efflorescence.

Efflorescence usually appears after long rainy periods. In summer the rain evaporates so quickly that comparatively small amounts of the salt are brought to the surface.

Efflorescence is an indication of absorption and any preventive measure must necessarily limit absorption to the point where insufficient water enters the mass to dissolve the salts and transport them to the surface.

While calcium carbonate efflorescence is practically insoluble in water, it is easily dissolved by a dilute solution of muriatic acid (1 part concentrated acid

to 5 to 10 parts water). Surfaces treated in this way should immediately be washed thoroughly with water. Walls should be thoroughly wetted with water before acid is applied. The acid wash should be tried out on a small, inconspicuous section of the wall to note its effect before proceeding with the whole job.

Cast Stone

Low absorption is the best assurance against efflorescence. Cast stone made from properly graded aggregates, with low-water cement ratio, puddled or compacted to produce maximum density and thoroughly cured, will have minimum absorption.

Rich, dense mortar in tight, well pointed joints will help keep water out of the wall and efflorescence from appearing on or close to the joints.

Stucco

With properly graded aggregates, stucco properly mixed is relatively free from efflorescence. Lime used to increase workability should be hydrated lime and free from calcium sulphate.

Light coloured stucco will show much less efflorescence than darker shades.

Stucco should be cured by sprinkling lightly and frequently, or should be protected to prevent evaporation that would render the stucco weak and porous, thus paving the way for excessive efflorescence later. This is especially necessary for the finish coat.

Concrete Masonry

In particularly porous concrete, the evaporation may take place back of the surface so that the deposit of salts while present is not visible unless the units are broken.

In extreme cases where efflorescence is unusually heavy it may be advisable to wash the wall with a muriatic acid solution, dry it thoroughly and apply boiled linseed oil, or a colourless commercial damp-proofing material.

Curing concrete in the presence of carbon dioxide gas appears to be beneficial in changing the calcium hydroxide to calcium carbonate. The carbonate seems to be formed in the pores at or just below the surface. The pores are thus partially or nearly filled, preventing the passage in or out of sufficient water to produce efflorescence. This method would appear to have possibilities in the manufacture of products.—(With acknowledgments to Portland Cement Association.)

LETTERS TO THE EDITOR

VILLAGE UPLIFT—GENERAL SURVEY IMPERATIVE

(The following article is contributed by one of our interested readers—Ed.)

To
 The Editor,
The Indian Concrete Journal,
 20, Hamam Street, Fort,
 Bombay

I have read with great pleasure and interest the importance you have given to the work of Village uplift, in the programme of post-war construction. I shall be thankful to you, if you can send me some details of practical demonstrations carried out at Virar by the Concrete Association of India.

I am making some experiments to deal with water-logging and water lifting, to suit village conditions. I shall be glad to send you details after satisfactory results are achieved.

I find most of the post-war reconstruction schemes are drawn up without giving any considerations to the existing conditions prevailing in the Towns and Villages. I have had an opportunity to visit some of the villages in the State and I found that even the fundamental and primary needs of the people are not provided for. If you wish to stay in a village you must carry water and provisions along with other things required for a mere existence. This state of affairs is very likely the same even in British India. Unless Villages and hamlets are made habitable, no agri-

cultural or industrial scheme is likely to benefit the mass of Indian population.

It must be realised that mostly from these villages the recruits for the army had been collected and during thus prolonged war they have acquired the knowledge of hygiene and their outlook on life and their standard of living had completely changed. It would be difficult for them to adopt themselves back again to their old mode of living. I am sure, this army when demobilised will leave their home and hearth and run to the nearest City, within a very short time.

It is an established fact that man's environments determine his health. This environment cannot be improved only by providing Hospitals and by preventive medicines. It needs introduction of sanitary measures that can only prevent diseases and ensure living comforts.

I consider that no stereotyped plan can suit all Towns and Villages of India. The condition of each town and village must be studied and they must be given special treatment to suit the circumstances. To improve a few towns and villages will not solve the problem. It is necessary to prepare a comprehensive and co-ordinated scheme with the help of a complete sanitary survey of all towns and villages of India. This survey will clearly show where and to what extent control of distribution of food-crops and

commercial crops have to be introduced, where transport facilities, marketing and other amenities are to be provided, where heavy industry may flourish and where cottage industries may prove beneficial. Such comprehensive survey can be completed within a space of two years, if all the Provinces and States undertake the survey work simultaneously on a common chalked out line.

To approach the subject on scientific basis it is essential to have a very clear picture of all towns and villages so that their situation, communication, soil condition, labour and material available, general health, prevalent diseases, quality and quantity of water supply, sanitary and economic condition, marketing facilities and other available amenities are correctly and clearly revealed.

Suitable proposals for future development can only be made with the help of such comprehensive survey which will clearly indicate the existing defects and the need of each town and village of the country. In fact all activities of post-war construction can only be regulated with precision and confidence with the help of such survey.

I hope you will be able to draw the attention of those that are responsible for the success of Post-war Planning works.

(Sd) XYZ

Note on Cement Concrete Roads by Chief Engineer,
Indian Waterproofing, published in the issue of May 1945

(1)

To
 The Editor,
The Indian Concrete Journal,
 Bombay

1. I congratulate the author for this attempt at a new design which may have set so many readers to thinking, on this important topic.

2. In this design, for a cement concrete Road, as put forward by the author, the expansion and the contraction in concrete are supposed to be provided for, by a system of half cuts in the road, alternately, at the bottom and top at intervals of 4 to 5 feet, and thus dispensing away with the necessity of usual expansion joints and use of bitumen filling at the joints. It has been stated by the author that the system of cuts as described would result in a counter-acting movement of top and bottom halves of the slab so that there will be no net contraction or expansion of the road, and to further explain the counter-acting movement it has been assumed that the top and bottom portion will act separately. This assumption, however, has not been reasoned out in any way by the author and appears to be doubtful.

3. In my opinion all that this design amounts to is providing the so-called dummy-joints at every 4 to 5 feet apart, with one difference that the joints,

instead of being all at the top, are alternately at the top and bottom. In the first instance, providing these cuts at such a close interval cannot be considered as sufficiently simple, as claimed by the author, so as to deserve any special merit over the present practice of providing expansion joints at longer intervals. In fact cuts being not through, there is no adequate provision for expansion due to temperature which could be considerable enough to cause arching of slab and consequent damage to it especially in a place of extreme climates and when the slab has been laid during cold weather.

4. Also the design under discussion is considered to have the following further snags in it.

a. In making the top cuts, the edges are likely to be disturbed at the time of withdrawing the iron flats. These edges if, therefore, left unprotected without any bitumen may start revealing under heavy traffic.

b. Due to the initial contraction in cement concrete during its setting there would appear through cracks along the cuts. If these cracks are not treated with any plastic material, rain water may penetrate through to the sub-grade thereby resulting in damage to the slabs.

c. If the condition of soil and nature of traffic call for use of reinforcement

in the slab, making of the suggested cuts would present practical difficulties.

5. One point in the design, however, is noteworthy and deserves attention and that is the method of making dummy joints at the bottom half of the slab by interposing a strip of wood in place. This joint would be somewhat neat and easier in construction than the usual surface dummy-joint and liable to revealing at the edges. Number of these bottom dummy-joints, say at intervals of 20 to 30 feet, with expansion joints at intervals of 60 to 90 feet, could be a practical proposition for the design of Cement Concrete Roads, in cases where reinforcement is not to be used in the slab. The dummy joints, however, after the cracks due to initial setting, would require to be treated with bitumen so as to prevent revealing of joints and infiltration of rain water to the sub-grade.

In the end, I would ask for your pardon if any of my comments are due to my inability to understand the design on account of brief description and would welcome further elucidation on the subject by the author.

(Sd) M. S. BHATIA,
 C.E.S., A.M.I.I.BOMBAY CENTRAL PUBLIC WORKS
 DIVISION, BOMBAY, 25-6-19

LETTERS TO THE EDITOR—*Continued.*

Refer Article "Note on Cement Concrete Roads" in your issue of May, 1945.

(II)

To
The Editor,
Indian Concrete Journal,
20, Hamam Street,
Bombay

It is not quite clear whether the author has tried such a construction anywhere and if so what is the duration of his observations and the details of his findings

From theoretical point of view the proposal appears to be unsound. The reason for providing construction joints is to allow for expansion and contraction of the slab which is more or less metallic in its behaviour. The function of bituminous fillers is two fold. Firstly to create a resilient surface at joints so that the pounding effect created by the impact at each joint owing to the unevenness in

every one knows, it is not so. The temperatures of the top surface and the bottom surface differ considerably and as such the expansion is also different. The warping of the slab is only due to this difference in temperatures and the theory of thickening the ends is based on the finding of this uneven temperatures in the same slab. The two joints theory as propounded would therefore serve no purpose

From the experience that I have of the behaviour of slabs I feel that a crack will definitely appear on the surface of the slab just above the lower joint.

It would be interesting to note at this place the effect that a staggard expansion joint has on adjacent slabs. There are several road slabs constructed by me in which for certain reasons the joint of the slab on half of the road width was not placed in line with the joint of the slab on other half width of the road but were

lines in line with the originally laid expansion joints.

It is therefore doubtful if the procedure suggested by the author will really serve any good purpose.

There is no doubt that a great amount of bitumen is wasted at present by the road Engineers who wish to be on safe side and sometimes to overcome the results of badly laid joints which in most cases is not due to any negligence on the part of the Engineers but due to dearth of intelligent workmen. If the slabs are laid in alternate bays and if the joints of intermediate bays are evenly laid and finished then a considerable quantity of bitumen will be saved

Observations are being carried out by me on half a mile of 22 ft wide C.C. Road, laid last year, with as even joints as it was practically possible to lay to ascertain what actually would happen if the joints were not filled in with bituminous material. The bays 11 ft wide and 30 ft long are laid alternately and as such the required expansion space is automatically secured. So far no deterioration of the slab at joints is observed. It is proposed to fill in joints after a year with bituminous material of high penetration to avoid thick "beadings" as one usually sees at every joint when filled with bitumen of low penetration. The pounding effect due to impact at each such joint is considerable and yet it is unfortunately ignored.

The suggestions made in the article under review are incorrect theoretically and unsound from practical point of view and as such should be accepted with caution unless of course they are backed by any actual observations on a finished job in which case elucidation of further details is necessary.

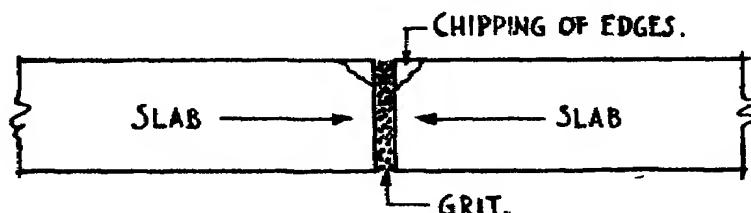


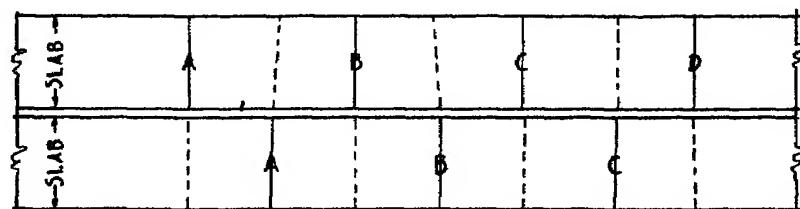
Fig. 1

adjoining surfaces be lessened and secondly to fill the joints with a plastic substance to avoid grit getting in between two surfaces at a time when slabs have contracted. This grit is liable to act as several wedges and disrupt slab when the slab expands. The pressure exerted during expansion is sufficiently great to chip off slab at edges as shown in fig. 1.

In the method recommended by the author it is not made quite clear how the author proposes to manipulate the camber of a wide slab. He has said at one place that "the Horizontal cuts, if required because of great widths of the road, be made at suitable distances." This point is not clear at all. Evidently the theory of Horizontal joint is not clear in the mind of the writer.

As regards making two joints on top and one joint at the bottom the author obviously presumes that the expansion of the bottom portion of the slab is the same as that of the top, although, as

staggard. In all such cases fresh cracks have developed in the slab in line with the joint of the other adjoining slab. To make it clear please see sketch below:



The original joints were spaced on each slab indicated as A, B, C, D. After a few months of the placing of the slab it was observed that cracks had developed in adjoining slabs as shown in dotted

(Sd) CHANDULAL C. DANGORIA,

M.Sc., M.I.E. (Ind.).

Hyderabad Dn, 28-6-45.

PUMPED CONCRETE REPLACES HANDSHOVELLING IN FEEDING ROTATING FORMS FOR PRESTRESSED PIPE

BY substituting mechanical pumping for hand-shovelling methods of feeding concrete into rapidly rotating forms for the manufacture of prestressed pipe in sizes from 12 to 60 in I.D., the Lewistown Pipe Co. of Chicago, has doubled output with one-half the labour force formerly used. The pipe, designed for internal pressures up to 200 lb per sq in., is made by first casting a concrete shell, in which longitudinal stress rods are incorporated, by the centrifugal process. After a period of steam curing, the shell is rotated in a special winding machine which wraps its outer surface spirally with high strength steel wire, applied under tension. In a third and final operation a 1-in protective coating of mortar is moulded over the wire-bound shell.

High Test Concrete

Concrete for the high-test, spun shell is of unusual design, with 12 bags of standard Portland cement per cu yd combined with crushed limestone and natural sand. One hundred per cent of the coarse aggregate passes a 1-in screen with 67 per cent of the combined aggregates passing a $\frac{3}{8}$ -in screen. The use of coarse ground cement facilitates the removal of excess water in the spinning operation. The concrete is initially mixed with approximately 4 gal of water per bag of cement. Spinning the pipe forms reduces the water to approximately $2\frac{1}{2}$ gal. per bag. The removal of this excess water, together with the compaction developed by centrifugal force, produces a concrete with compressive strengths of 12,000 to 15,000 lb per sq in. and a density of 159-161 lb. per cu. ft.

The mixing plant and arrangement for pumping the concrete shells includes batch hoppers under a two-compartment 50-ton aggregate bin discharging on to a short vibrating screen and belt conveyor

which riddles off the oversize aggregates and foreign materials and relays the batch into the skip of a 21-E paving mixer where bag cement is added. The mixer discharges into a $1\frac{1}{2}$ -cu. yd remixing hopper of a 160 single Rex Pumpcrete mounted on a self-propelled carriage with 25-ft travel between mixer and forms, this distance being required to provide clearance between the end of the withdrawn discharge pipes and the spinning machine for the handling of the 12-ft pipe forms. When the sidewall thickness of the shell is greater than 2 in., concrete is placed in two operations to avoid segregation of the materials and to facilitate the removal of all excess water.

Forms

All pipe sizes are cast in 12-ft lengths. The steel forms are fabricated in two sections, bolted together for convenient assembly. Cast-steel end-rings, which serve as rolling tracks, are held fast to the steel forms by longitudinal rods running the full length of the form and threaded on both ends. These rods, spaced approximately 6 in on centres and set 1 in inside the steel form, are tightened by wrench until each rod is under a stress of 30,000 lb. per sq. in. They are incorporated in the concrete when the shell is spun to provide the longitudinal pre-stressing. When the nuts are removed, the tension in the rods is held by the bond of concrete, developing a longitudinal compression of 90 lb per sq in.

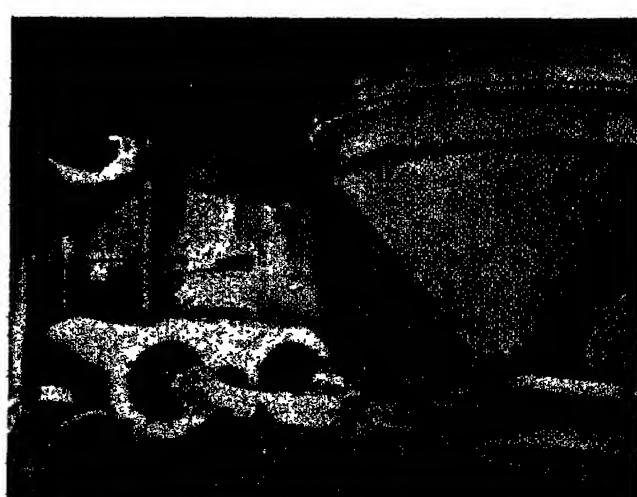
The rolls of the spinning machine are adjustable for width to accommodate the various size forms which ride at an approximate angle of 45 deg, from centre of form to centre of rolls. It is essential that the cast-steel end-rings be accurately machined and the forms in almost perfect balance or they will jump the rolls when revolving at high speed.

Spinning and Pumping

At the start of a pour, two sets of forms are lifted by chain hoists from the end of the form-assembly line and placed in position on the spinning machine. The loaded Pumpcrete is rolled forward until the ends of the twin delivery pipes are about 1 ft from the end of the forms. The spinning machine is started at 90 rpm. Concrete is deposited in equal proportions in each form as the Pumpcrete carriage is slowly withdrawn. Depending on the size of pipe, from 2 to 4 min are required to place one-half of the concrete in each form. Then the speed of the spinning machine is stepped up to 250 rpm for 5 min. In this short period centrifugal force packs the concrete against the forms, driving all excess water to the inner surface.

Meanwhile, the Pumpcrete has been rolled back to the mixer for a fresh batch of concrete and is ready for the second and final pass, after the spinning machine has been stopped and water broomed out of the form. When the second layer of concrete has been deposited and the spinning machine again has been stepped up to full speed for another 5-min. run, a man at each end of the forms holds a bar tool designed for the purpose against the inner edge of the revolving form-head to draw the I.D. of the pipe to exact size. A high degree of accuracy is obtained in this manner, as centrifugal force makes the material seek a uniform thickness inside the form. Excess water is removed in the final operation by sliding a bar in and along the pipe invert.

When the final spinning operation has been completed, all of the excess water has been removed and the concrete presents a hard polished surface. After the pipe has been carefully inspected, the completed sections are removed by an other set of chain-hoists at the far end of the spinning machine and rolled on to



FRONT AND REAR ENDS of pair of pipe forms in place on rolls that rotate them during centrifugal casting process. At left are shown within pipe forms, ends of twin 5-in.-dia. discharge pipes from Pumpcrete machine in background. At right, twin discharge pipes are closely connected with Pumpcrete unit below hopper which feeds concrete into cylinder of machine.

a steam-curing rack. After 24 hr. of steam-curing the forms are removed from the concrete shells, cleaned and reassembled.

One of the features of the pumping operation is the high degree of accuracy obtained in depositing the exact amount of concrete required to fill the various size forms, thus holding waste to a minimum. The consistency of the concrete can be held close enough to assure a uniform rate of production through the

pump. After a short experimental period the travelling speed of the pump carriage was readily synchronized with pumping speed to distribute the correct volume of concrete for each set of forms.

It was also quickly discovered that it is necessary to clean thoroughly both of the twin 5-in discharge pipes from the pump after the completion of each day's operation to assure an equal distribution of concrete into each of the two forms. As long as these discharge pipes are spot-

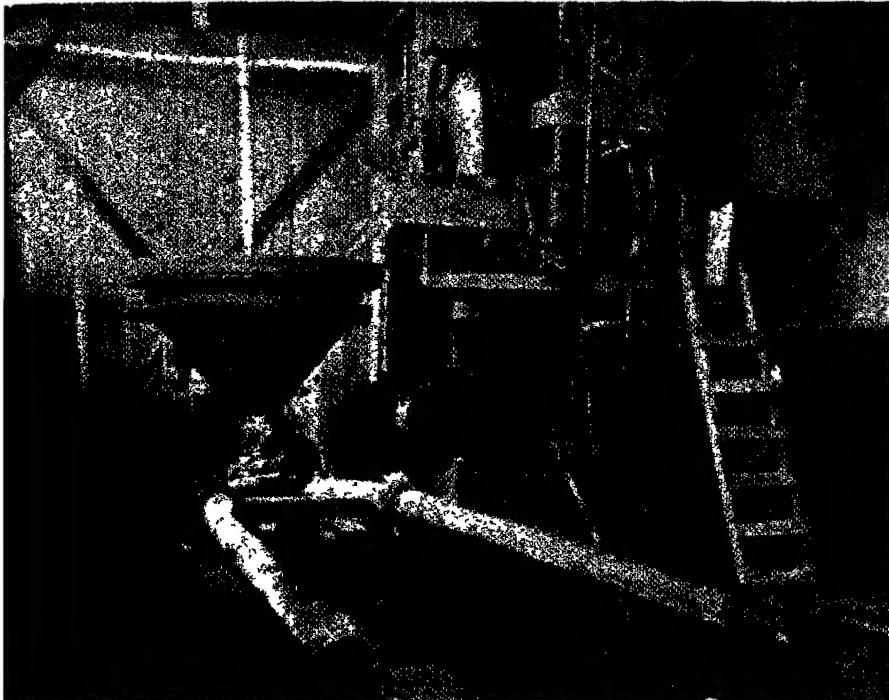
less at the start of the day's run they will deliver an equal flow of concrete. If one pipe is fouled with patches of concrete residue from a previous run, it will lag behind the production of the other.

Pumpcrete Economy

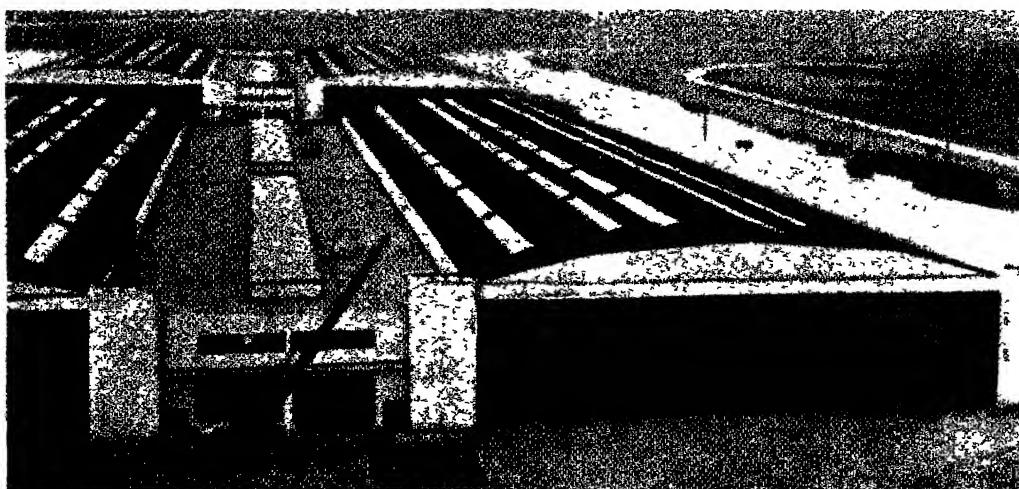
Use of the Pumpcrete for this work has resulted in a 50-per cent labour saving and doubled the output of the plant as operated by hand-placing methods. In other words, one-half as many men can turn out twice the previous daily volume of pipe with the one spinning machine setup. Formerly an 8-man crew was required to maintain an average of 2 pipe lengths per hr. By use of the Pumpcrete setup the average has been boosted to 4 pipe lengths per hr with a 4-man crew who batch the aggregates, dump the cement, operate the mixer, Pumpcrete and spinning machine and handle the pipe forms.

The reason for the labour reduction is more or less self-evident. The time element is affected because the concrete is pumped into the forms faster than it can be shovelled by hand and the spinning period is reduced approximately 50 per cent (from 10 to 5 min) because the pump handles a much stiffer mix and distributes it more evenly. The initial water content of the mixed concrete has been reduced from 5 gal to 4 gal per sack of cement. As previously stated, the spinning process ultimately reduces the water content of the fresh concrete in the finished pipe to approximately $2\frac{1}{2}$ gal per sack of cement, so that 40 per cent of the excess water is eliminated at the start by use of the Pumpcrete.

At the present time one spinning machine is adequate to service the requirements of this plant, but it is estimated that with the addition of two or three men to the gang, the Pumpcrete could just about keep three sets of rolls going, thus greatly increasing production at any time an appreciably larger output is desirable.—(*With acknowledgments to "Construction Methods."*)



TRAVELLING CARRIAGE carries Pumpcrete and its horizontal twin discharge pipes that feed concrete into rotating pipe forms. Length of travel is sufficient to cover 12-ft. length of pipe. In background is 2½E paving mixer that feeds hopper of concrete pump.



AIRPLANE MODIFICATION CENTER in Oklahoma, recently completed in 92 days by Corbett Construction Co., of New York, for U.S. Engineer Department, provides 622,700 sq. ft. of floor space in two 160×600 ft. hangars separated by two-storey 100×600 ft. shop and office building. Hangar design provides for 160 ft. steel roof trusses spaced 25 ft. on centres and supported by 18×24 in. concrete columns. Shop building is reinforced concrete structure, with 16×18 in. columns and concrete girders. Outer walls of both buildings are of concrete blocks. Work was carried on 24 hr. a day. Architect-engineers for project, which cost about \$ 4,500,000 were Syerdrup & Parcel, of St. Louis and J. Gordon Turnbull, of Cleveland.—("Construction Methods.")

A MILLION-GALLON ELEVATED TANK AND RESERVOIR

ONCE upon a time it was possible to disclose the site of the reservoir and elevated tank which form the subject of this article. The district they supply expanded rapidly prior to the outbreak of war, and, as the area is well above the level to which the gravitation supply will rise, it became necessary to increase the water storage capacity for the area by the construction of a reservoir with a capacity of 1½ million gallons and a one-million-gallon elevated tank 37 ft 6 in. above the reservoir, the tank being provided to supply the highest points of the area above the level of the new and existing reservoirs.

The following notes have been written for this journal by the consulting engineers for the work.

For a structure of such magnitude reinforced concrete offered the best possibilities. As the structure is situated in a prominent position the aesthetic treatment of the tank was of prime importance, and an architect collaborated with the consulting engineers in the design of the elevations. Almost all large elevated tanks are circular in plan, as this shape has the advantage of enclosing the greatest area in a given perimeter, but the cost of the circular shuttering is high compared with the shuttering required for a rectangular tank. In general, however, the floor slab of a circular tower consists of a dome springing from circular arches or beams, which in turn are supported on columns,

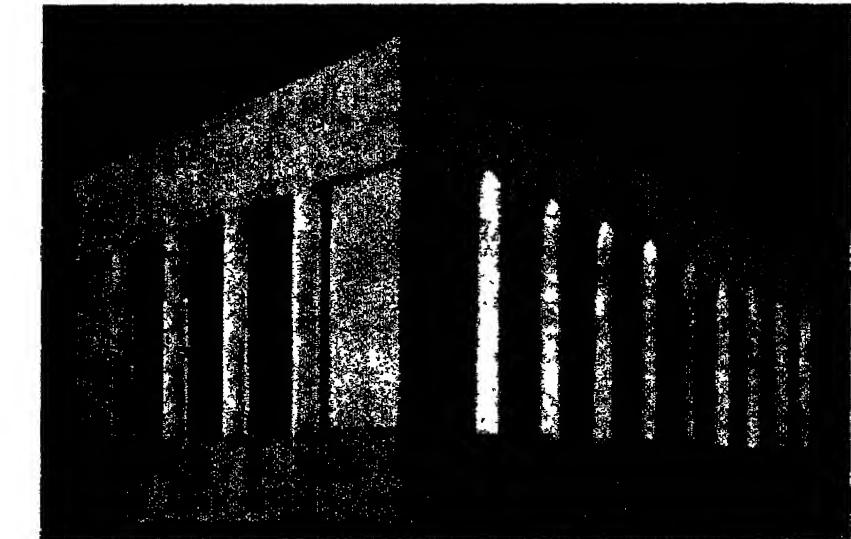


Fig. 1.

carrying the load direct to the foundations, and from the point of structural efficiency the arrangement is a good one. Unfortunately the labour cost on circular towers is high and the appearance generally, in the opinion of some critics, is not good unless the tank is of small capacity at a great height, when a slender and not unpleasing structure can be obtained. The rectangular type of elevated tank, supported on numerous small

columns with horizontal bracing, may produce a rather ugly structure, and it was with these facts in mind that the design for the present tank was conceived.

It will be seen from Figs. 2 to 6 that both the reservoir and tank are divided into two equal compartments by means of twin division walls separated by a ½-in. layer of bituminous sheeting. The halves are designed to act independent-

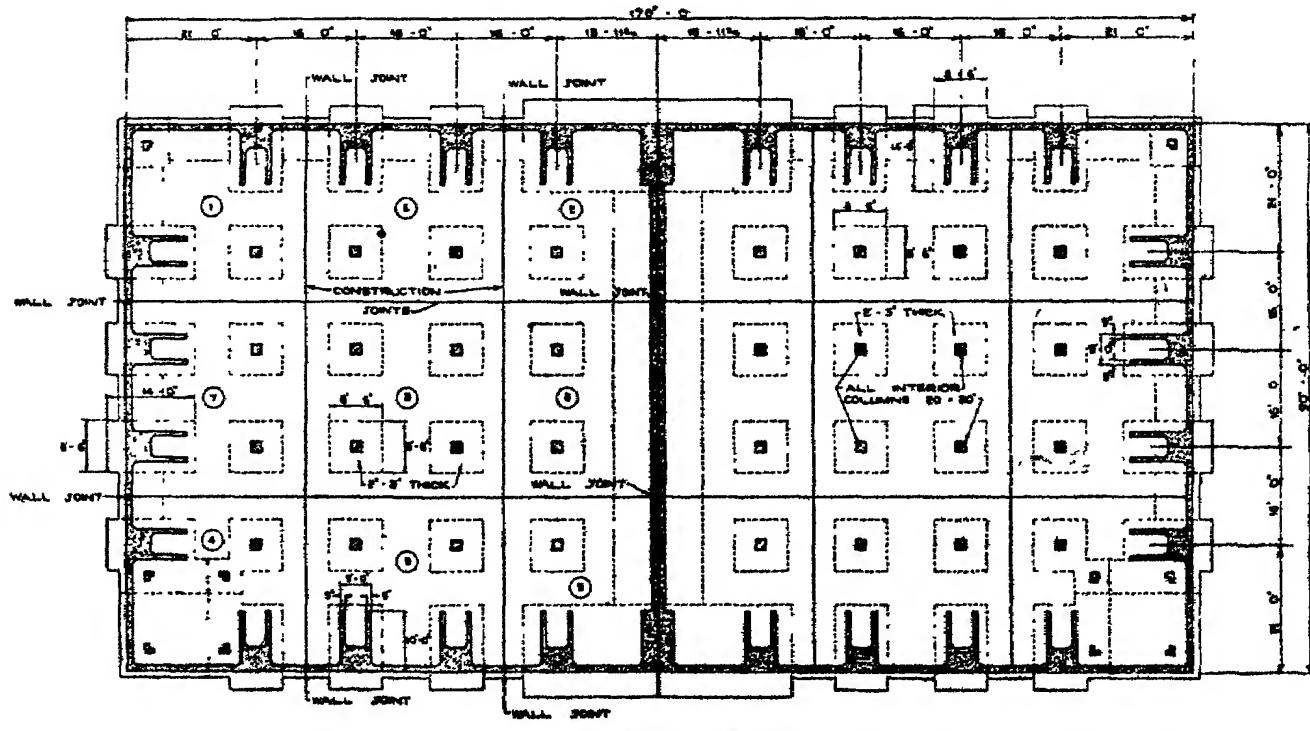
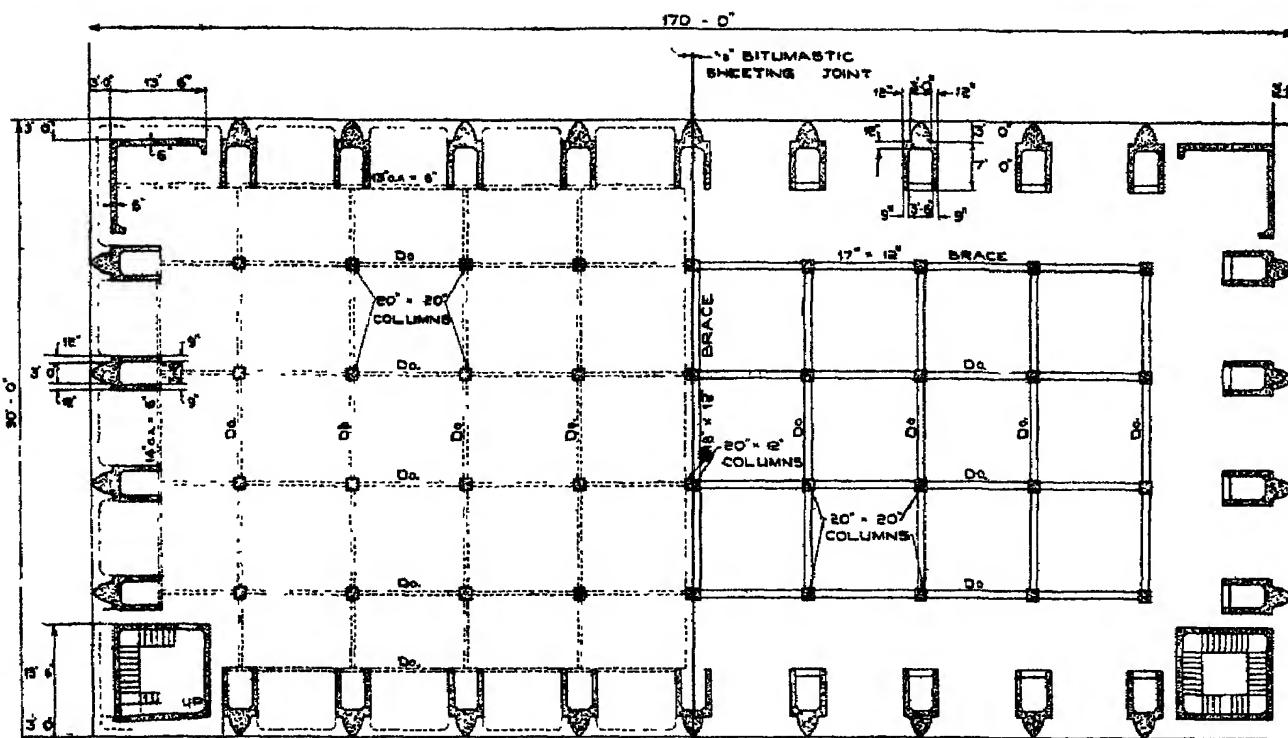


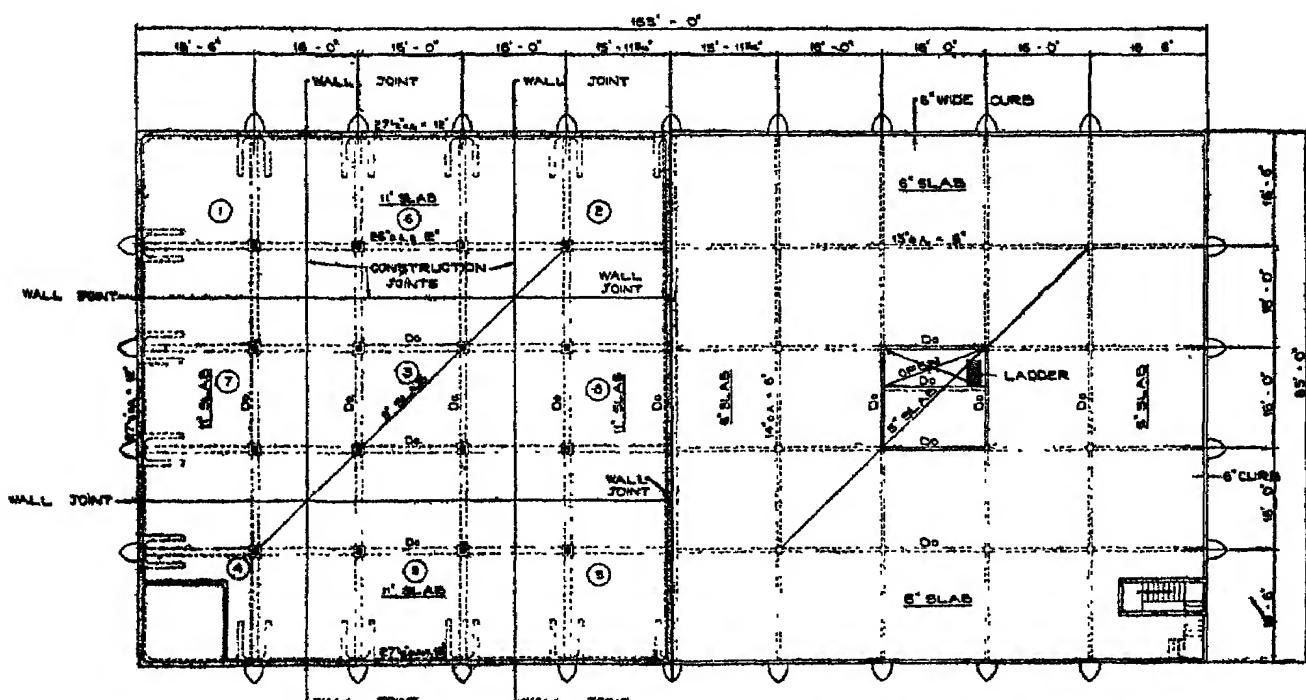
Fig. 2.



HALF PLAN OF RESERVOIR ROOF

HALF PLAN AT COLUMN BRACES

Fig. 3.



HALF PLAN OF TANK FLOOR

HALF PLAN OF TANK ROOF

Fig. 4.

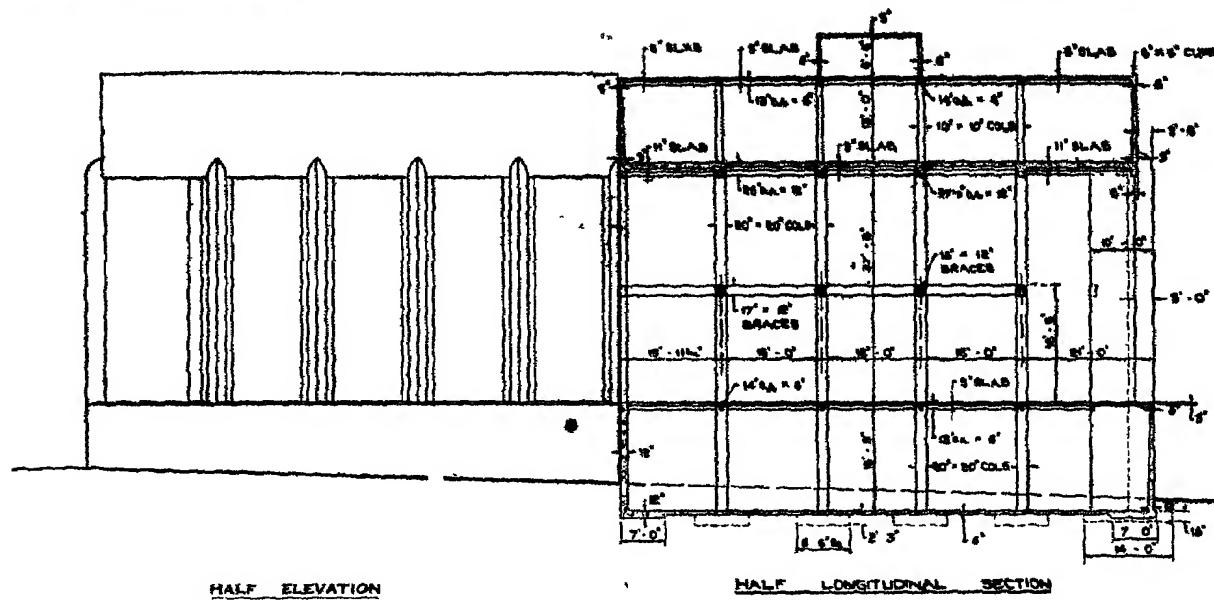


Fig. 5

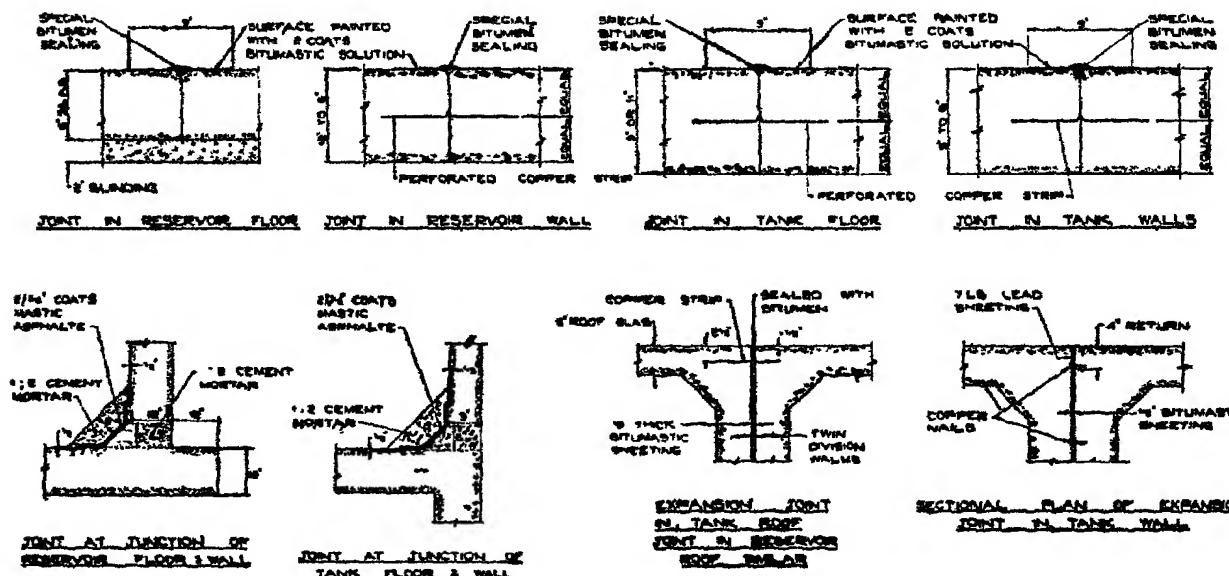


Fig. 6.

of each other. The elevated tank is a simple rectangular box, perfectly plain, carried on internal columns with horizontal bracing and with large streamlined outer columns of hollow construction. At two of the four corners of the tank there are square towers inside which is a staircase from the roof of the reservoir to the roof of the tank; at the other two corners mock towers are carried up to provide the necessary supports to the corners of the tank and to preserve the aesthetic effect. Means of access to both the reservoir and tank are provided.

Details of the construction joints used are illustrated in Fig. 6. The floor of the reservoir was divided into nine

approximately equal areas and was concreted in alternate panels in numerical order as shown in Fig. 2. The $\frac{1}{2}$ -in. deep vee-groove at the top of the slab was formed with a timber fillet nailed to the stopping-off board. Before laying new concrete against set concrete, the face of the set concrete was roughened by hand picking, cleaned, damped, and coated with 1 in. of stiff cement mortar immediately prior to laying the new concrete. Before setting the vee-joint with the bituminous material, the joint was brushed clean of dirt and dust, first with a steel brush and finally with a soft hair brush, the joints were then cleaned of fine dust with compressed air and tho-

roughly dried with a blow-lamp. Before the concrete had cooled a thin coat of bituminous material, about $\frac{1}{16}$ in. to $\frac{1}{8}$ in. thick, was applied to the surface of groove with a warmed special metal trowel working the coat firmly against concrete faces so as to ensure efficient adhesion. After the primary coat had been applied the groove was then filled with the bituminous material via a warmed shaped metal jointing tool the filling was pressed firmly against primary coat to ensure complete adhesion and watertightness. On completion of the bituminous filling, together with concrete face for a width of $\frac{1}{2}$ in. either side of the joint, was pair-



Fig 7

with two coats of bituminous solution. A similar joint was used in the walls of the reservoir and the tank and in the tank floor, with the addition of a perforated copper strip.

The walls of both the reservoir and the tank were divided into panels by vertical joints placed midway between the main outer columns and in line with the joints in the floor, concreting was again carried out on the alternate panel principle and the wall was concreted in one operation for its entire height. Horizontal day-work joints, always a potential source of weakness in a water-containing structure, were thus eliminated.

It will be seen from Fig 6 that at the junction of the floor and wall, in both the reservoir and the tank, the bottom 6 in. of the wall and the 6-in by 6-in splay are constructed of 1 ½ cement mortar. The junction of the floor and wall of a water containing structure is always the weakest point so far as watertightness is concerned, for that reason special measures are invariably adopted. In this instance the concrete of the floor slab was thoroughly cleaned and roughened where it was to come into contact with the wall and splay. The 1 ½ cement mortar, mixed fairly stiff was then placed in position and was followed immediately by the structural concrete, which was thoroughly rammed into the cement mortar. Further protection against leakage at this point is provided by the ½-in. mastic asphalt covering to the splay, the asphalt in turn being protected with a 6-in covering of 1 ½ cement mortar. The main joint dividing the structure into two equal compartments was formed by ½-in thick bituminous sheeting on the exposed faces of the elevation the sheeting was wrapped with 7-lb sheet lead which prevents the unsightly stains which often accompany this type of joint when the bituminous sheeting is left exposed to the elements.

The supply and discharge pipes to the elevated tank are accommodated in the hollow outside main column. Where the pipes pass through the walls or floor special castings were made. These castings were double-flanged, with a special flange cast on at the centre, they were placed in position and concreted in with the work, and the space between the flange and face of the concrete was caulked with mastic asphalt. When the reservoir and tank were filled with water these connections proved very satisfactory and showed no sign of leakage.

On completion, the reservoir and tank were filled for testing and left for fourteen days. On examination a few leaks were discovered, some of which disappeared after a few days, at the other leaks the concrete was cut out and made good. One or two of these leaks appeared along a definite line and

it was found that at these points concreting had been stopped during the workmen's lunch period. It was discovered also that these stoppages occurred during a fairly warm spell of weather. It would appear that during this short stop in the pouring of the concrete a partial set had taken place, thus forming a weakness. In water containing structures it seems necessary that a special clause should be inserted in the specification that during concreting the workmen's meal hours must be staggered to ensure continuous concreting of a panel.

The joints generally gave complete satisfaction, the only joints to show any leakage were the wall joints in the elevated tank. It would appear, therefore, that in a relatively thin member such as the tank wall there may be difficulty in obtaining a thoroughly watertight joint with the perforated copper strip. In a 6-in wall there is not much space available for the concrete to be rammed thoroughly around the bars and the copper strip so as to obtain an ideal key through the perforations, which is necessary for this joint. During the whole period of the test there was no appreciable drop of the water level in either the reservoir or tank, showing that the leakage was of a very small nature.

The work was started in May 1939, and the eighteen months specified for completion was exceeded by some fifteen months. Owing to the longer period required to construct the work, the concrete was exposed to the weather to dry out and a longer period allowed to elapse before the tanks could be filled with water. This delay was probably the cause of a slight dampness which appeared at some points on the walls. This dampness was overcome by painting the inside of the tank and reservoir with two coats of bituminous paint of a type that is especially suitable for use in structures containing drinking water.

(Continued on page 126)

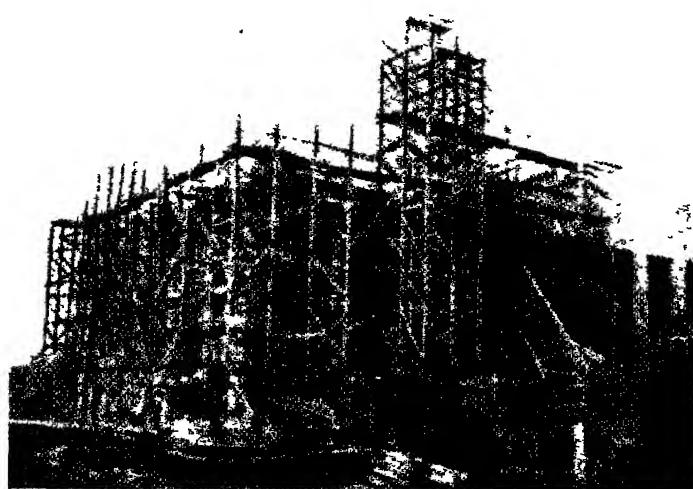
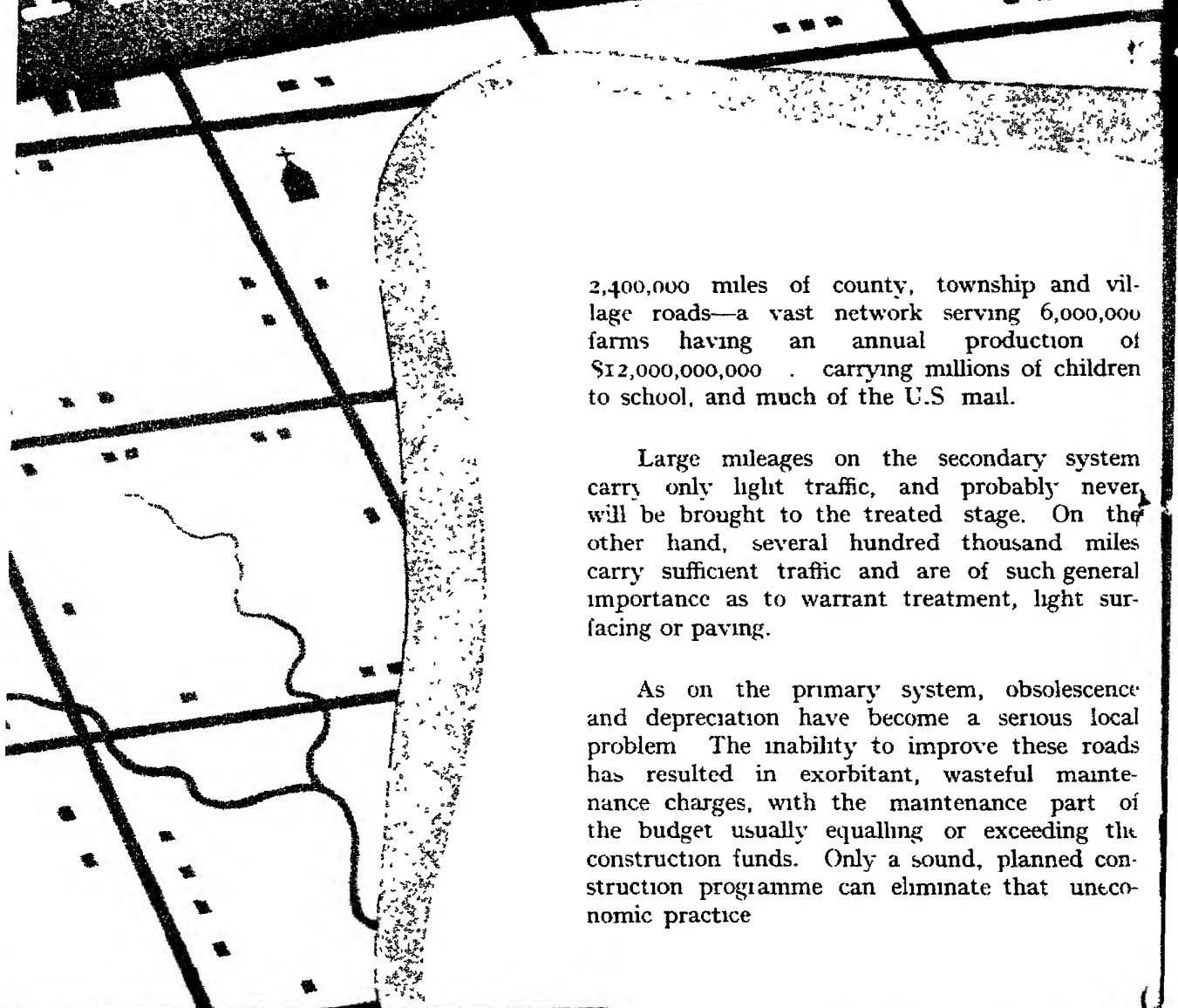


Fig 8.

Make no little



This map of a typical county highway system demonstrates the importance of secondary roads in the National economy.

2,400,000 miles of county, township and village roads—a vast network serving 6,000,000 farms having an annual production of \$12,000,000,000 . carrying millions of children to school, and much of the U.S mail.

Large mileages on the secondary system carry only light traffic, and probably never will be brought to the treated stage. On the other hand, several hundred thousand miles carry sufficient traffic and are of such general importance as to warrant treatment, light surfacing or paving.

As on the primary system, obsolescence and depreciation have become a serious local problem. The inability to improve these roads has resulted in exorbitant, wasteful maintenance charges, with the maintenance part of the budget usually equalling or exceeding the construction funds. Only a sound, planned construction programme can eliminate that uneconomic practice

Plans for SECONDARY ROADS

The entire nation has a direct and deep-seated interest in county and local roads. Over these roads must flow a large part of farm produce, yet 42 per cent of the farms are still on dirt roads. Better rural roads will speed up shipments from farm to city, and reduce food costs . . . make it possible to consolidate an estimated 5,000 rural schools . . . eliminate the severe handicaps against which Rural Free Delivery now struggles during spring break-up periods, and whenever the weather is bad.

Jobs must be waiting when the war is over . . . jobs for eight to ten million men in the armed services when they come home. Improvement of secondary roads will spread the work, and provide thousands of jobs where they do the most good . . . in a man's home county.

"Make No LITTLE Plans" for secondary roads.

AUSTIN-WESTERN COMPANY • Aurora, Illinois.

BUILDERS OF ROAD MACHINERY
Austin  **Western**

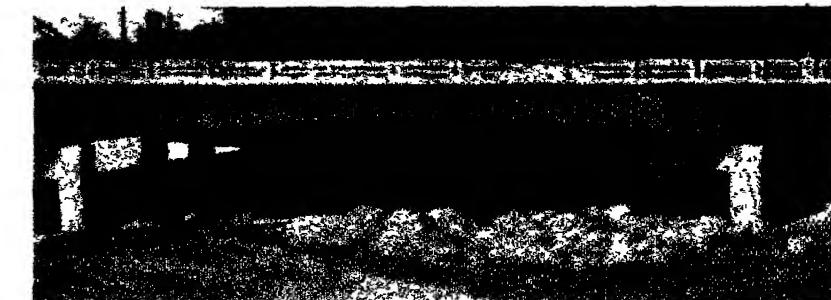
BUY MORE
WAR BONDS

footings, but long pile clusters upon which to rest them. In general, piles extended below footings approximately 63 ft., with cut-off elevation 23 ft. below natural ground line. Altogether, for the two abutments and the three piers at Miller Road interchange, 404 piles were driven. Bearing capacity of the piles was found to be 20 tons at this penetration.

The depth of unstable material required excavation for footings to an average of around 25 ft. below ground line. Inasmuch as the Detroit Industrial Expressway met no intercepting highways at a right angle, pile spacing had to be accommodated not only to the condition of the subsurface, but to the angle at which the two roadways met.

Concrete Slab Construction.

Typical roadway construction was of 12-in. uniform section slab, built without steel except for that used at trans-



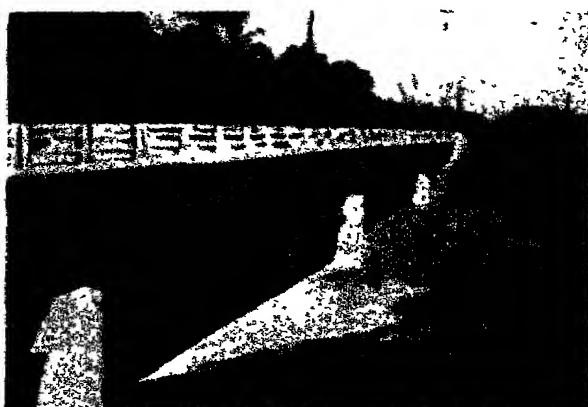
verse joints (which followed Michigan specifications for size and spacing of bars) and for the use of tiebars in some construction joints. Where steel was used at contraction joints $\frac{1}{2}$ -in. round bars 4 ft. long were placed at a height of one-half the thickness of the pavement and spaced on 40-in. centres. The groove left by the steel bar forming the contraction joint was filled with joint

filler, or a premolded filler was inserted. Where premolded joint filler was used, the edging adjacent to it was omitted.

One of the new features of construction was provision for mailbox turnouts. In general, these turnouts were of uniform thickness metal built out on the shoulder extending a minimum of 80 ft from one end of the turnout to the other. Six cubic yards of material was needed for a one-box turnout with 0.3 cu. yd. for each additional turnout. Turnouts extend to within 12 in. of the mailboxes.

Concrete slabs, normally 60 ft. wide if not of divided construction, sloped both ways from the centre to yield a $\frac{1}{4}$ -in. crown at the curb. Finish grade line of concrete pavement is 6 ft. above new compacted subgrade material.

Bridges and interchanges are built with 5-ft sidewalks with a 2 ft 9 in. overhang. Lighting conduits are integral with sidewalk construction. In general, hand rails are cast-in-place. Architectural embellishment is given all elements of bridges, rails, piers, wing walls, and so on.—(With acknowledgments to "Concrete.")



In many cases bridges were built before the undercrossing highway had been graded

A MILLION GALLON ELEVATED TANK AND RESERVOIR—(Continued from page 121.)



Fig. 9.

Figs. 1 and 7 show the finished structure and the inside of the reservoir. The large outer hollow columns look very well indeed and give the structure an appearance of solidity which could not have been obtained with normal column and horizontal brace

construction. Figs. 8, 9 and 10 show the staging and scaffolding, the copper strip joints in the wall, and the reinforcement in the tank floor beams. The total cost of the work, excluding piping, was £22,400, including painting the interior of the reservoir and elevated



Fig. 10.

tank walls.

The elevated tank of one million gallons capacity is, as far as the writer knows, the largest of its type in Great Britain, if not in the world.—(With acknowledgments to "Concrete and Constructional Engineering.")

SOIL-CEMENT PAVEMENTS

THE stabilisation of soil with cement is continuing to make considerable progress in the United States, and will, no doubt, be used as a form of construction where suitable in Australia in the post-war period.

A summary of all pavements constructed in the United States up to the end of 1942 shows that nearly 30,700,000 square yards of pavement were laid in the form of runways, roads, floors, etc., and of this total approximately half was put down during the year 1942.

The fact that the Highway Research Board of America has issued a specification dealing with this type of construction is indicative of the progress it has made.

Summary of Procedure.

To ensure success, certain simple precautions have to be taken. Their importance cannot be over-emphasised. Briefly, the procedure in the construction of soil-cement pavements should be as follows:

- 1 Establish a soil profile by means of a soil survey.
- 2 Determine cement content and moisture control in the laboratory with soil samples that bear a relationship to the soil survey.
- 3 Scarpify existing pavement to a sufficient depth to allow compaction of 6 inches of pavement.
- 4 Evenly spread a predetermined amount of cement over the area.
- 5 Thoroughly dry mix cement and soil.
- 6 Properly compact the pavement with sheep's foot rollers having complete unit pressures.
- 7 Grade and remove top compaction planes.
- 8 Finally roll with a smooth wheel roller.
- 9 Cure properly.

Controlled factors essential for field success are determined in the laboratory as follows—

- 1 Proper cement content.
- 2 Proper moisture control, and
- 3 Proper density.

It is therefore essential that field control should be undertaken to relate construction methods to laboratory determination.

Provided that the above simple procedure is followed, success can be confidently anticipated.

SOIL-CEMENT MIXTURES.

The following data are compiled for the information of Australian engineers from a bulletin issued by the Highway Research Board of America dealing with the use of soil-cement mixtures.

MATERIALS.

Cement.

Portland cement shall be of Australian origin manufactured in accordance with the Australian Standard Specification A2-1939.

Water.

Water must be free from excessive amounts of oils, alkalis, salt or organic

material. Any potable water is suitable for soil-cement.

Soils.

Test records show that a majority of the soils used successfully in soil-cement construction fall within the following grain size limits:

Maximum size: 3 in.

Passing No 4 sieve. At least 50 per cent

Passing No 40 sieve 15 to 100 per cent.

Passing No. 200 sieve. Not more than 50 per cent

Limits of physical test constants for these same soils are as follows:

Liquid limit. Not more than 40

Plasticity index. Not more than 18

These limits for grain size and physical test constants cover soils occurring widely in the United States. Soils having higher silt and clay contents and higher liquid limits and plasticity indices have been used successfully. However, the cement requirements and the cost of pulverising and mixing are usually high for such soils, and it may be more economical to import soils from nearby sources that will require less cement and may be processed with greater ease.

In general, any soil that can be pulverised economically can be used in soil-cement construction. In this connection, a word of caution is necessary to the engineer inexperienced in such work, since many soils which appear difficult to pulverise may be made mellow and capable of ready pulverisation by proper pre-wetting to permit absorption. Repeated experience has shown that farmers can give valuable suggestions on the moisture condition which best lends itself to ready pulverisation of the soil in a locality.

Soil Surveys, Sampling and Analyses.

Soil survey and sampling procedures should follow the recommendations of the A.S.T.M. tentative methods D 420-42 T or the A.A.S.H.O. standard methods T 86-42. Soil analyses should be conducted in accordance with the A.S.T.M. standard methods D 422-39 to D 427-39 inclusive—A.A.S.H.O. T 88-42 to T 94-42 inclusive. Soil groups or classifications later referred to are those recommended by the Public Roads Administration Highway experience also shows the advisability of identifying the soil horizon or profile of the sample. Frequently tests will show that the "A" horizon topsoil requires more cement than underlying soils. In such instances it may be economical by selective grading, to waste the "A" horizon soil, in case normal grading operations do not remove it, and use underlying soils. Wasting the "A" horizon materials is usually economical, in those areas where trees are the natural surface vegetation. Where surface vegetation is scarce or where it consists of grasses, it is common practice to use the "A" horizon.

In addition to identifying the horizon or profile of the soil being tested, it is also good practice to relate the soil series to

surveys previously made and published by the Bureau of Chemistry and Soils, U.S. Department of Agriculture, since it is known that the cement requirements for each horizon of a particular soil series will be practically the same wherever the soil series may occur. Thus, test records may be established which show the cement requirements for each soil series and horizon, thereby reducing the subsequent soil-cement testing to a simple check test.

Cement Requirements.

The quantities of cement required to harden soils are determined by testing soil-cement mixtures with varying cement contents in accordance with the wetting and drying test of compacted soil-cement mixtures, A.S.T.M. tentative method D 559-40 T (Appendix 2) and the freezing and thawing test of compacted soil-cement mixtures, A.S.T.M. tentative method D 560-40 T (Appendix 3). The cement requirement usually ranges between 8 and 14 per cent by volume.

The following criteria for determination of cement requirements based upon test results are recommended:

- 1 Losses during 12 cycles of either the wet-dry test, A.S.T.M. D 559-40 T (Appendix No 2) or freeze-thaw test, A.S.T.M. D 560-40 T (Appendix No 3) should conform to the following standards.
- Public Roads Administration Soil Classifications A-2 and A-3 not over 14 per cent
- Public Roads Administration Soil Classifications A-4 and A-5, not over 10 per cent.
- Public Roads Administration Soil Classifications A-6 and A-7, not over 7 per cent.
- 2 The maximum volume at any time during either the wet-dry test or freeze-thaw test should not exceed the volume at time of moulding by more than 2 per cent.
- 3 The maximum moisture content at any time during either wet-dry test or freeze-thaw test should not exceed that quantity which will completely fill the voids of the specimen at time of moulding.
- 4 Strengths of soil-cement specimens, tested in compression at various ages after 1 to 4 hours soaking in water, should increase with age and with increases in cement content in the ranges of cement content producing results meeting requirements of items 1, 2 and 3.

The general physical relations of soils and compacted soil-cement mixtures are brought out clearly by a study of the soil groups and cement contents for suitable hardness and durability, which are tabulated in Fig 1. This shows that there is a rather wide range of cement contents required to harden satisfactorily the range of soils in each soil group; also, that certain cement contents predominate in each group. Of the soils studied, 141 were of the A-2 group. The A-2-4, A-2-6 and A-2-7 soils were included in the A-2

group in all studies. One hundred and eleven soils (79 per cent), gave satisfactory results with cement contents of 6, 8 or 10 per cent, by volume. The data also show that 63 soils (45 per cent) gave satisfactory results with 8 per cent cement by volume and indicate the generality that 8 per cent cement will be satisfactory for about half the A-2 soils.

The grouping brings out further that soils do exist which will give satisfactory

general conclusion. The procedure followed in some laboratories is to compare an available soil with similar soils already tested from the same area, and use this comparison as a basis for the preliminary selection of the cement content requirement.

Moisture Density Requirements.

The moisture-density relationship for soil-cement mixtures is determined in the

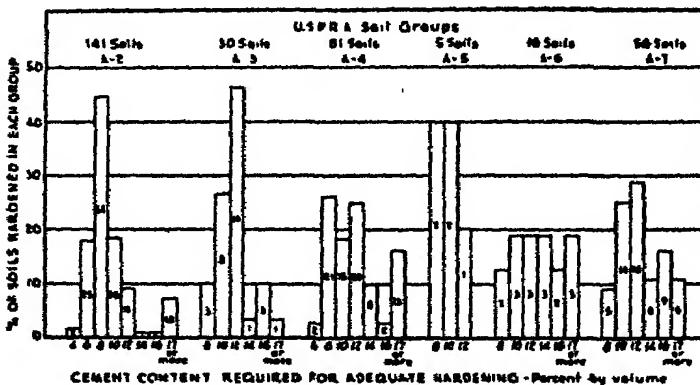


FIG. 1.
U.S.P.R.A. Soil Groups.

results with 4 per cent cement and also that some A-2 soils may possess characteristics which require quite high cement contents for satisfactory hardening.

In the A-3 group of 30 soils available for study, 22 soils (73 per cent) required 10 or 12 per cent cement. The lowest cement content was 8 per cent and the highest was 16 per cent.

Of the 81 A-4 soils available for study, 56 soils (69 per cent) required 8, 10 or 12 per cent cement.

There is a definite trend toward increased cement requirements with increases in silt and clay content. The A-2 soils fall generally into the 6, 8 and 10 per cent cement content groups. The A-3, A-4 and A-5 soils fall generally into the 8, 10 and 12 per cent cement content groups, and the A-6 and A-7 soils fall generally into the 10, 12 and 14 per cent cement content groups.

It is also apparent that there is a general overlapping of cement content requirements in the various soil groups.

However, these data do not show one important general characteristic of all soil groups. In a particular locality or small area, the cement content requirements for each soil group will be constant and will in general fall within a range much narrower than those indicated above. As pointed out under "Soil Surveys, Sampling and Analyses," a specified soil horizon of a soil series, as identified by the Bureau of Chemistry and Soils, U.S. Department of Agriculture, will probably have a constant cement requirement.

Until the required cement contents for soils in a particular locality are known, those most likely to give successful results are indicated by this study of 329 soils for 37 States. (Fig. 1.)

It should also be emphasised that tests on hundreds of other soils reinforce this

laboratory by A.S.T.M. method D 558-40 T (Appendix No 1). This test procedure is also used on field construction toward the conclusion of damp mixing operations to determine the field optimum moisture content for use in connection with placing and rolling the soil-cement mixture.

CONSTRUCTION.

Soil-cement is usually built to a 6 in compacted depth. Greater depths cannot be compacted to the required density in one layer with sheep's-foot rollers and manipulation costs on less thickness are about the same. When the base course thickness is greater than 6 inches, it should be processed in two or more layers.

Equipment.

Recent construction experience has demonstrated that a system of "train" processing results in the most efficient use of equipment and accurate control of processing operations. The procedure is followed after the roadway has been prepared for processing by grading, pulverising, and levelling operations.

The equipment which may be used for an efficient, balanced operation for fine grading and pulverising prior to processing consists of:

- 1—motor grader, 12 ft. blade (tandem or 4-wheel drive preferred).
- 2—9 ft offset disc harrows, minimum diameter of discs 24 in.
- 2—4 bottom, 14 in. mouldboard ploughs
- 2—6 ft. rotary tillers.
- 6—tractors, 35 D.B.H.P.

The following is a similar balanced list of typical equipment which may be used on mixing operations.

- 2—8 ft. heavy duty spring-tooth cultivators, equipped with 4 in. shovels.
- 2—4 bottom, 14 in. mouldboard ploughs.
- 2—6 ft. rotary tillers.

- 1—1,000 gal. water pressure distributor.
- 2—1,000 gal. water feeder tanks or preferably pressure water distributors.
- 1—power controlled auto patrol, 12 ft. blade (tandem or 4-wheel drive preferred).
- 6—tractors, 35 D.B.H.P.

Compacting and finishing equipment for use after processing consists of:

- 2—double drum sheep's-foot rollers, heaviest loadings practical, types to be dictated by soil conditions, ranges of foot pressures to be approximately

For sandy soils, specify unit pressures of 50 to 100 lb. per sq. in. with tamping feet of 10 to 12 sq. in. area. (Very sandy soils free of binder may be compacted satisfactorily with pneumatic and smooth rollers.)

For sandy loams and light clay loams, specify unit pressures of 100 to 200 lb per sq. in. with tamping feet of approximately 7 sq. in. area.

For more plastic soils and soils containing considerable aggregate, specify unit pressures of 200 to 400 lb per sq. in. with tamping feet of 5 to 6 sq. in. area.

- 1—tandem self-propelled smooth wheeled roller, heaviest load practical, size to be dictated by soil conditions.
- For sandy soils, specify 3 to 5 tons.
- For sandy loams and light clay loams, specify 5 to 8 tons.

For more plastic soils and soils containing considerable aggregate, specify 8 to 12 tons.

- 1—multiple wheel pneumatic tyre roller
- 1—10 ft spike tooth harrow, teeth not more than 1½ in. apart
- 1—broom drag.
- 1—nail drag
- 2—tractors, 35 D.B.H.P.
- 2—tractors, 20 D.B.H.P.

The equipment listed for pulverising, with the exception of the disc, is used also on processing and duplication of equipment is not required. Also, many soils can be pulverised adequately and rapidly with the spring tooth cultivators, ploughs and rotary tillers used in processing, and in this case the offset disc harrows are not required.

This equipment list may be increased or decreased to fit local conditions. On small jobs, one piece of each basic type equipment may suffice. It is important that no more work be laid out for a working day than can be completed with the available equipment. Under no circumstances should cement be spread, road mix produced or plant mix material prepared or delivered in excess of that which can be readily completed to final surface finish, including all joints or connections, within daylight hours, allowing for occasional breakdowns and other delays.

A well trained and well organised engineering and construction force can produce from 4,000 to 6,000 ft or more of 20 ft roadway (8,900 to 13,300 sq. yd) in a 12-hour day with the equipment listed above and an adequate cement and water supply.

Construction Procedures.

Soil-cement construction procedures are specified by many highway department and other engineering organisations.

Experience has shown that the construction details discussed in the following paragraphs need constant attention.

Grade Preparation and Pulverisation: The roadway section is bladed to the grade and crown required in the finished work. Forms are not needed as the width of construction is defined by stakes. After grading is completed, the soil is loosened to a depth of $\frac{1}{2}$ in or to $\frac{1}{4}$ m. less than the required thickness and pulverised until at least 80 per cent, exclusive of stone and gravel, passes a No. 4 sieve. As noted previously, the control of the moisture content of heavy textured soils at time of pulverisation will facilitate this operation. The rotary tillers and disc harrows, when needed on the heavier textured soils, are effective pulverising tools when used in conjunction with the gang ploughs and field cultivators, which bring the bottom lumps to the surface for pulverising. The depth of initial scarifying is checked carefully and the depth is controlled by the setting of the gang ploughs. It is customary practice for the contractor to assign a foreman to pulverising operations and this foreman is held responsible for depth control.

Equipment used in processing also is used in pulverising operations. While cement is being spread early in the morning and during packing operations at the close of the day, when the equipment is not needed for mixing operations, it is used to pulverise the soil required for subsequent work.

Spreading Cement: The spotting and spreading of cement is usually done by hand methods. The cement spreading crew is trained to spread each bag of cement in a transverse row over the area assigned to it. The use of properly marked longitudinal and transverse spreading chains is recommended. As soon as the cement has been spotted and spread in one "train lane," the final longitudinal spread is obtained by repeated trips of a spike tooth harrow which is followed by the soil-cement mixing operations.

Bulk cement trucks and cement spreading devices, when available, may be used instead of hand spreading operations. They are efficient and effective on contracts involving 100,000 sq yds or more.

Mixing Operations: The mixing of soil, cement and water is accomplished by mixed-in-place or plant methods. The mixed-in-place method using field cultivators, ploughs and rotary tillers is the more common and has been used on a very large percentage of the work completed to date. The plant method utilising various paddle type travelling and stationary mixers has been used largely on contracts involving one-quarter million square yards and more.

The important points to be watched with both types of mixing operations are noted in the following paragraphs.

Mixed-In-Place Procedures: Details of mixed-in-place construction are shown as follows:

Dry Mix: The equipment for the first round trip in dry mixing consists of the cultivators and rotary tillers. Ploughs are not used, since they would throw

unmixed cement to the bottom of the section, from whence its recovery is difficult in subsequent mixing operations. The depth of treatment should be checked carefully at this point, and any needed adjustments made.

Under favourable conditions, one round trip of the equipment will result in proper depth and width and produce a sufficiently uniform mixture of soil and cement to permit most mixing operations to follow at once.

Moist Mix: The first trip of the train in the moist mixing operations should include the heavy duty gang ploughs in the position back of the field cultivators. The pressure distributor for the application of water is placed in the train back of the rotary tillers. When two distributors are used, the second one is added to the train back of the spring tooth field cultivators and ahead of the first gang plough.

Each piece of equipment maintains its position in the train and manipulation continues until sufficient water has been added to meet field optimum moisture requirements and provide an excess sufficient to compensate for evaporation losses during compaction. After the water has been added, mixing should continue if necessary until the mixture is uniform.

The total capacity of water hauling and distributing equipment should be checked carefully to make sure it is adequate for the maximum day's work. For example, a section 20 ft wide and 2,000 ft long may require 50,000 gal of water in case the soil is air dry at the time processing operations begin and no water has been added previously.

Moist mixing operations may be shortened by adding water to the pulverised soil the previous day. This water is partially mixed in with ploughs and rotary tillers to reduce evaporation losses to a minimum and to give uniform distribution through the mixture.

Experience and research have shown that clay balls in the mass must be moist throughout at the time compaction operations begin. In some cases pre-wetting will be helpful in accomplishing this result.

In order to give uniform mixtures at the edges and to properly confine the material being processed, it is important to have a trench or furrow at the outside edge during most of the moist mixing operation. The trench or furrow is formed by the gang plough supplemented by the motor grader.

Experience and research have shown that, due to an increase in mixing time, the optimum moisture requirements for field mixtures of soil-cement, ready for compaction, are higher than the results obtained with laboratory mixtures containing the same quantities of cement and soil. Therefore, it is necessary to obtain data in the field laboratory and plot a moisture-density curve in accordance with A.S.T.M. tentative method 558-40 T (Appendix 1) using material from the nearly completed mixture. It is important that the field optimum moisture taken from such a curve govern the water requirements on construction. The moisture content of the mixture at

the time of compaction may be as much as 110 per cent of the field optimum without detrimental effect. Moisture contents below field optimum may result in inferior construction.

Uniformity and Depth of Treatment:

It is recommended that a member of the contractor's force be trained so that, during both dry and wet mixing he can co-operate with the engineer in determining the uniformity and depth of the mixture. A satisfactory check on these points may be made by digging a trench to the undisturbed sub-grade across the full width of the processed material. The trenches are dug at intervals of 200 to 500 ft, depending upon the length of section being built, and observation of the exposed edges and excavated material indicates the uniformity of the mix. Measurements from a grade line stretched between grade stakes on opposite sides of the road or by the use of "T" boards on opposite grade stakes has resulted in good depth control. The man charged with the gang plough operation works with this checker to obtain the required control.

Machine Mixing:

Various paddle type travelling and stationary mixers have been used for soil-cement construction. They are best adapted to large contracts. Each type has its own mixing characteristics and the operation must be so controlled as to insure a uniform mixture of soil, cement and water. Most plans work efficiently when they are so adjusted that the soil and cement are mixed thoroughly before final water requirements are added and mixed. Checks on the completed mixture should include critical attention to the presence of cement balls, water concentrations and similar non-uniform conditions. The use of some travelling type mixers requires that the pulverised soil be windrowed, while others process the pulverised soil directly in place.

These machines replace the "train" processing equipment and procedures. However, the initial pulverising and final compaction and finishing operations are the same for all types of mixing equipment.

Compaction and Finishing Operations:

Upon completion of moist mixing operations, the sheep's-foot rollers move in on the "train lane." Compaction starts at each edge, progresses to the centre of the lane and back to the edges to permit the rollers to pack out uniformly. More rolling may be necessary at the edges than at the centre to obtain the required density. When the feet of the sheep's-foot rollers are being supported to within about an inch of the surface, spike tooth harrows should be used to comb or loosen the surface to eliminate compaction planes. As sheep's-foot rolling and harrowing progress, the road should be continuously shaped to the required crown with blade graders. During these operations moisture determinations must be made frequently and water applied as necessary to maintain optimum moisture continuously and uniformly throughout the area being shaped. When sheep's-foot rollers are

no longer effective, spike tooth harrows are replaced by nail drags and broom drags for continued but lighter shaping and dressing. The final surface finish is obtained by rolling with pneumatic or smooth wheel rollers. It is essential that the harrowing be adequate to break out any compaction planes near the surface and that the blading and shaping and the application of additional moisture be correlated to produce the required surface, uniformly moist and dense with no compaction planes. Since sheep's-foot rollers are not effective in compacting sands of uniform grain size, the required density may be obtained with pneumatic or smooth wheel rollers. The density of completed work should be as high as practicable and never less than 5 lb below maximum, as shown by field moisture-density tests.

Testing Compacted Materials: The compaction and cement content of completed work may be checked by means of the following tests.

Methods of Determining Density of Compacted Layer: The density of a soil layer may be determined by finding the weight of a disturbed sample and measuring the volume of the space occupied by the sample prior to removal. This volume may be measured by filling the space with a weighed quantity of a medium of predetermined weight per unit volume. Sand, heavy lubricating oil or water in a thin rubber sack may be used. Except for the determination of the weight per cubic foot of the medium, the three procedures are the same and therefore the one using sand will be described in detail. It is as follows:

1. Determine the weight per cubic foot of the dry sand by filling a measure of known volume. The height and diameter of the measure should be approximately equal and its volume should be not less than 0.1 c ft. The sand should be deposited in the measure by pouring through a funnel or from a measure with a funnel spout from a fixed height. The measure is filled until the sand overflows and the excess is struck off with a straight-edge. The weight of the sand in the measure is determined and the weight per cubic foot computed and recorded.

2. Remove all loose soil from an area large enough to place a box and cut a plane surface for bedding the box firmly. A dish pan with a circular hole in the bottom may be used.

3. With a soil auger or other cutting tools bore a hole the full depth of the compacted lift.

4. Place in pans all soil removed, including any spillage caught in the box. Remove all loose particles from the hole with a small can or spoon. Extreme care should be taken not to lose any soil.

5. Weigh all soil taken from the hole and record weight.

6. Mix sample thoroughly and take sample for moisture determination.

7. Weigh a volume of sand in excess of that required to fill the test hole and record weight.

8. Deposit sand in test hole by means of a funnel or a measure by exactly the same procedure as was used in determination of unit weight of sand until

the hole is filled almost flush with the original ground surface. Bring the sand to the level of the base course by adding the last increments with a small can or trowel and testing with a straight-edge.

9. Weigh remaining sand and record weight.

10. Determine moisture content of soil samples in percentage of dry weight of sample.

11. Compute dry density from the following formulae.—Volume of base mixture =

wt of sand to replace base mixture

weight per cubic foot of sand

Wet wt per c ft. = $\frac{\text{wt of base mixture}}{\text{vol. of base mixture}}$

Dry wt per c ft = $\frac{\text{wet wt per cu ft}}{\text{per cent moisture}}$

$\frac{100}{\text{x + 100}}$

For example, assume the weight per cubic foot of sand = 100 lb, weight of wet material from auger hole = 57 lb, moisture content of soil = 15 per cent, and weight of sand to fill auger hole = 4.5 lb. Then the volume of base mixture from hole = $\frac{4.5}{100} = 0.045 \text{ c ft}$, the wt

per c ft of wet base mixture = $\frac{57}{0.045} = 126.7 \text{ lb}$; and the wt per c ft of dry

base mixture = $\frac{126.7}{15} = 110 \text{ lb}$

Assume that optimum moisture $\frac{15}{100}$

for this base mixture is 15 per cent. and maximum density is 115 lb per c ft, then the compaction in the layer tested

is $\frac{110}{115} \times 100 = 95.7 \text{ per cent}$

Moisture Content: The moisture content of soil-cement mixtures is usually determined by evaporating to dryness the sample taken in making density tests.

Chemical Determination of the Cement Content of the Finished Mixtures: When laboratory facilities are available it will be of great value to determine the uniformity of the cement distribution in the completed mixture. These data covering the first few days' processing will be of particular value in pointing up any discrepancies in construction methods and controls, thus permitting improvements to be made that will secure the desired uniformity as construction proceeds. This information also will be of value later in studying the service life of the completed project. Representative samples of the cement are taken during construction and at least three samples of the raw soil should be taken across the road or lane being processed at selected control points. These three samples may be combined or analysed individually. Samples of the finished mixture are then taken at the same control points and at as many additional points as may be necessary to determine the uniformity of cement content. The methods used for this analysis are described in Appendix 4.

Curing.

Under emergency conditions, soil-cement may receive a bituminous prime

immediately after the final rolling. However, when possible, a cover of hay, straw, earth or waterproof paper should be placed immediately after the soil-cement is completed and left in place for seven days. Hay, straw or earth should be kept moist during the curing period. After seven days the cover should be removed, the surface cleaned and left open for 14 days or until convenient to place the bituminous prime and surface

Type and Quantity of Bituminous Prime.

Tars of the grades RT-2 and RT-3, having Engler specific viscosity of from 8 to 22 at 40 deg. C., or rapid-curing asphalts of the grades RC-1 and RC-2 may be used for priming soil-cement base courses.

The quantity of tar or asphalt prime required will vary from 0.15 to 0.25 gal per sq yd, depending upon the character of the surface. The maximum quantity should be used that will not result in the bituminous prime collecting in pools or running from the surface. After a proper seasoning period (a minimum of 24 hours), excess prime may be blotted up with sand.

Bituminous Surfaces.

The general practice is to cover soil-cement base courses with a bituminous wearing course of some type. The design and construction of bituminous pavements is not within the scope of this report, but a survey of 68 projects made by the committee and reported in Volumes 20 and 21 of the Highway Research Board Proceedings shows that surfaces varying in thickness from $\frac{1}{2}$ in to 2 in have given satisfactory service. A large proportion of the bituminous wearing courses reported were $\frac{1}{2}$ in thick. Armour coats, surface treatments, road mixes and plant mixes have given satisfactory service. Tars, cut-back asphalts and asphalt cements have been used successfully in various types of treatment.

Preparing Soil-Cement Surfaces for Bituminous Prime and Mat.

The practice in preparing the surface of a soil-cement base for a bituminous prime and surface is very similar to that followed in cleaning crushed stone, gravel, and other aggregate surfaces. The surface of the soil-cement base should be free of dust and in a moisture condition suitable to receive the particular type of bituminous prime to be used.

All loose and inferior material should be removed from the surface to expose hard, satisfactory soil-cement. A motor grader, set firmly against the surface is generally used to loosen and remove the major portion of inferior surface material. Square point shovels are used to clean up small areas requiring additional attention. Then the entire area is brushed clean with rotary power broom which is followed by a blower to remove surface dust. Small areas can be cleaned satisfactorily with hand fibre brooms.

After cleaning, minor irregularities may be smoothed up by patching with a suitable bituminous-aggregate mixture in order to produce a uniform surface

upon which to place the bituminous surface course.

Construction Precautions.

Examinations of existing pavements in which the base courses are composed of soil-cement mixtures show that defects which shorten service life may be traced to inadequate attention to the following items—

Preparation of the Sub-grade: In addition to supporting the pavement after it is put in service, the sub-grade serves as a base for rolling the cement-water mixture to the density indicated by the design. Therefore, special attention should be given to the preparation of the sub-grade and to the elimination of spots having inadequate bearing capacity. Since the uniformity of the cement content, and of the thickness of the finished base course are dependent upon the condition of the original sub-grade, special attention should be given to producing a uniform cross-section before scarification is started.

Preparation of Mixture: The uniformity of the finished mixture is dependent upon the distribution of cement and water and the skilful operation of the mixing equipment. Constant visual inspection and frequent moisture tests should be made during mixing operations. The results of chemical analysis made on samples taken at frequent intervals will serve as a check on the uniformity of the mix. If such analyses indicate non-uniform cement contents, a careful check should be made of all mixing operations. The work should be planned so that rolling and finishing will be completed within the final setting time of the cement.

Weather Conditions: Pulverisation of soil should be avoided during wet weather. Application of cement and water and the processing of the mixture should not be carried on during wet weather or when the temperature is likely to fall below freezing point. During hot, dry weather, special attention should be given to the maintenance of the water content required for the hydration of the cement in the mixture, for compaction to the required density, and for satisfactory finishing.

Surface Finishing: Finishing operations should be performed in a manner designed to avoid unsatisfactory surface conditions due to rapid drying, formation of planes of weakness, placing of thin layers to bring the surface to satisfactory line and grade, or other undesirable conditions.

MAINTENANCE AND RECONSTRUCTION.

Repair and Patching of Soil-Cement.

*Areas where the soil-cement requires rebuilding or where surface blemishes are more than 2 in. deep should be repaired by rebuilding with soil-cement for the full depth. Similar soils of the same density, moisture content and cement content as used originally should

be used in making the repairs. In some cases, maintenance consists of patching and repairing areas of various shapes and irregular sizes. Such areas are repaired by excavating them down to satisfactory sub-grade, squaring the edges and filling with premixed soil-cement which is compacted in 3 in layers and finished. Soft sub-grades under the patch area should be excavated and graded and a stable sub-grade prepared with aggregate or compacted soil-cement backfill.

The soil-cement mixture may consist of materials from the same sources as those used in the original construction or of borrow materials meeting the specifications previously listed.

Generally, patching materials are mixed in paddle or pug-mill type mixers or by mixed-in-place procedures on some convenient area. Hand mixing should be used when the patches are small, relatively few in number.

The following compaction and finishing tools may be used, depending on their availability and the work at hand.

- Hand tampers.
- Compressed air tampers
- Single-section sheep's-foot rollers
- Pneumatic-tyre roller or available trucks
- Smooth steel roller.
- Hand rakes.
- Water tank (spray bars or hose)

When soft sub-grades are encountered or increased load carrying capacity is needed, construction consists of building the soil-cement patch or reconstruction in two or more 6 in. layers. The existing material is utilised insofar as possible. When insufficient for the depth of construction planned, the underlying soil is processed in 6 in. layers, and then sufficient surface material for the top 6 in. layer is bladed back and processed with cement.

Large areas requiring reconstruction are built in conformance with soil-cement construction practice previously described.

Where it is not possible to pulverise the soil-cement in place within reasonable time or expense, it is removed and suitable soil is imported for processing the area. In some cases the structural value of the existing soil-cement may warrant leaving it in place and placing an additional 6 in. layer of soil-cement upon it.

Salvaging and Reconstructing Low Cost Pavements with Soil-Cement.

Soil-cement can be used for rebuilding existing low cost roads and streets requiring maintenance or reconstruction. Work of this nature complying with present day standards has been done with:

Caliche	macadam
clay-gravel	sand-clay
crushed stone	shale
gravel	shell, and similar materials.
limerock	
marl	

For such operations, materials already in place or readily available are generally used.

The materials in the existing pavement or sub-grade and any imported soil used in reconstruction should meet the requirements for grain size and physical constants given in the section on materials. In most cases the suitability of the material in place will be determined by the quantity passing the No. 4 sieve. Where the amount passing the No. 4 sieve is insufficient, fine material should be imported and added as required to make a mixture complying with the requirements. Such fine material may consist of any readily available friable soil. When the sub-grade consists of heavy textured soils requiring high cement content, sand, gravel or other coarse material may be imported and added as necessary to make a suitable mixture. Topsoils ("A" horizon) containing sod, decomposed vegetation, etc., should not be used.

A cement content of 10 per cent by volume (0.45 bags per sq. yd. of 6 in. compacted depth) generally will give adequate hardness and strength to material from the existing pavements or from selective borrow containing from 25 to 50 per cent aggregate retained on a No. 4 sieve. Those containing less aggregate generally will require 12 per cent cement by volume (0.54 bags per sq. yd. of 6 in. compacted depth). The A.S.T.M. soil-cement tests (Appendices 2 and 3) should be conducted to confirm these estimates.

The construction procedure to be followed is as described for new work or for patching depending upon the size of the operation.

Soil-cement construction is also used to widen roads and streets.

Field Testing.

The optimum moisture content and maximum density requirements for use in control during construction may be taken from the moisture-density curve plotted from the data obtained by testing the soil-cement mixture in accordance with A.S.T.M. Tentative Method D 558-40T (Appendix 1).

When soil-cement work with untested materials totals less than 500 sq. yd., the following "emergency testing procedure" may be used. This procedure may not determine the most economical mixture, but it will provide cement contents that are adequate for this condition. Mould six test specimens of optimum moisture and maximum density with two specimens containing 10 per cent cement, two containing 12 per cent cement and two containing 14 per cent cement by volume. Remove the specimens from the moulds and store in an atmosphere of high humidity, in damp sand or under damp burlap for 7 days. After 7 days soak the specimens in water for at least 4 hours and then test in compression. Suitable cement contents will be indicated by compressive strengths of 500 lb. per sq. in. or more. In case the work is in surface sands or gravels, two additional test specimens containing 16 per cent cement should be made and tested—(With acknowledgments to "Constructional Review.")

A MOBILE LABORATORY FOR TESTING CONCRETE

CONTROL testing during the execution of a contract is now recognised as an important means of securing the desired degree of quality in materials and workmanship. With a large programme of public works in prospect after the war, increasing use is likely to be made of this form of control, and for certain types of work a testing laboratory on the side has obvious advantages over the remoter methods of control.

The following brief description of a mobile laboratory for testing concrete has been issued by the Road Research Laboratory of the Department of Scientific and Industrial Research, Harmondsworth, West Dravton, Middlesex, principally for the information of engineers and surveyors who may be contemplating setting up a similar unit.

The Road Research Laboratory will be pleased to supply further information on request, or to arrange for the laboratory's unit to be inspected by appointment. In addition to the concrete-testing unit the laboratory has mobile units for testing soils and for carrying out analyses of bituminous materials. Particulars of these will also be supplied on request.

General Description.

The laboratory is mounted on a 6-ton four-wheel trailer chassis. The body is 17 ft long, 7 ft 6 in wide, with an internal height of 6 ft 6 in. The general lay-out is shown in Fig. 1. Other details are shown in the photographs. The trailer was specially built to designs prepared by the Laboratory and is equipped for Standard cement tests, examination and testing of aggregates, tests for controlling concrete quality, such as the measurement of moisture in aggregate

and slump tests, making concrete cubes and testing for compressive strength, and general experimental work on concrete and other constructional materials.

Except on unusually steep gradients the trailer can be hauled by a 4-5 ton lorry.

Services.

Gas Supply—Heating is by means of butane (Calor gas) stored in liquid form in cylinders, each containing enough for about two weeks' normal use. Storage space is provided for two space cylinders. Gas taps of the usual laboratory type are fitted at various points in the benches.

Electricity Supply—The electricity supply is obtained from a 15 KVA 240-v single-phase petrol driven alternator. The alternator can be operated in its normal carrying position under the bench, but provision is also made for sliding it out on to a trestle outside the laboratory so that it can be run without causing vibration. The alternator supplies current for lighting and for various items of apparatus, such as the sieve shaker and the mortar cube vibrator. When ordinary mains current is available near the working site connection can be made by means of a cable carried in the laboratory and the apparatus used without the alternator. Emergency lighting is provided by a 12-v 180-amp-hour accumulator charged either from the alternator or from the mains supply.

Water Supply—A supply of water is carried in a 30-gallon tank mounted above the main bench. Two sinks are fitted in the bench, one with a waste outlet leading directly out of the laboratory, the other with a waste outlet leading to a second tank beneath the bench from which the water can be returned to the supply tank by means of a semi-rotary hand pump. By means of this arrangement water used in certain operation can be reused. External fittings allow mains water to be used to fill the supply tank or to be connected direct to the internal system. Alternatively the pump mentioned above can be used to fill the storage tank from external supplies.



Interior View—Looking Forward showing 100-ton Testing Machine in Background and Bunks in Right Foreground.

Sleeping Accommodation—Sleeping bunks are provided for two persons. The upper bunk can be turned over and used as an auxiliary bench or set to act as a back rest when the lower bunk is used as a seat.

Fume Cupboard—A fume cupboard with electric extractor fan is provided at one end of the main bench.

Concrete Curing Tanks—A curing tank to hold thirty-six 6-in cubes is fitted beneath the lower bunk.

Apparatus and Equipment.

The main items of fitted equipment are as follows:—

(1) Hand-operated 100-ton hydraulic compression testing machine, having a second pressure gauge giving a range up to 25 tons. This machine weighs about 9½ cwt and was constructed especially for this laboratory.

(2) Standard mortar cube vibrator made according to B.S. 12.

(3) Electric sieve shaker.

(4) One 7-kg and one 1-kg. semi-automatic balance.

Other apparatus normally carried includes—

(1) Cement-testing apparatus (according to B.S. 12).

(2) Set of B.S. sieves from 1½ in. to No. 100.

(3) Cube moulds (3 in., 4 in. or 6 in., as required). Storage space for up to about twenty-four or more 6-in moulds is provided in lockers that open both inside and outside the laboratory.

(4) Slump apparatus.

(5) General apparatus such as bunsen burners, drying trays, trowels, scoops, floats, measuring jars and thermometers.

Cost.

Under present conditions the trailer and its equipment, purchased on the basis of previously prepared working drawings and specification, would cost about £1,000 to £1,500—(With acknowledgments to "The Surveyor," London.)

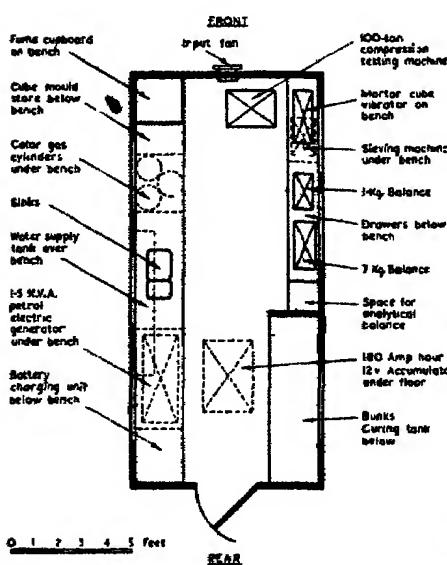


Fig. 1.—Lay-out of Mobile Laboratory.



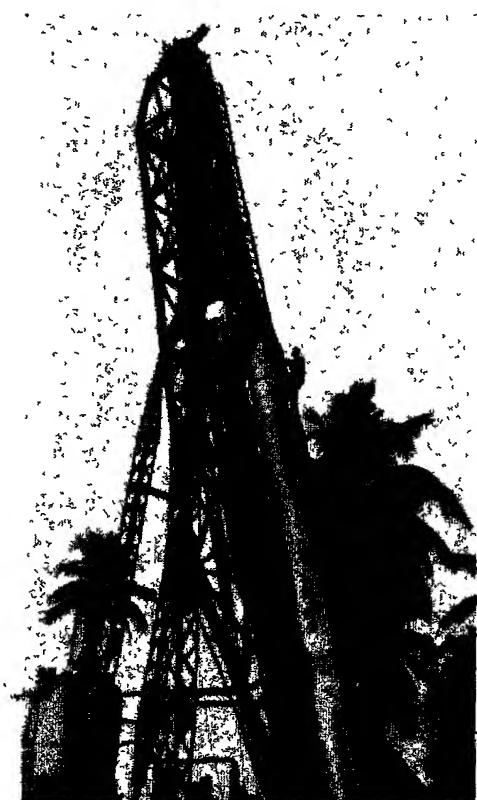
View of Laboratory, showing Cube Mould Store and Generator Compartment.



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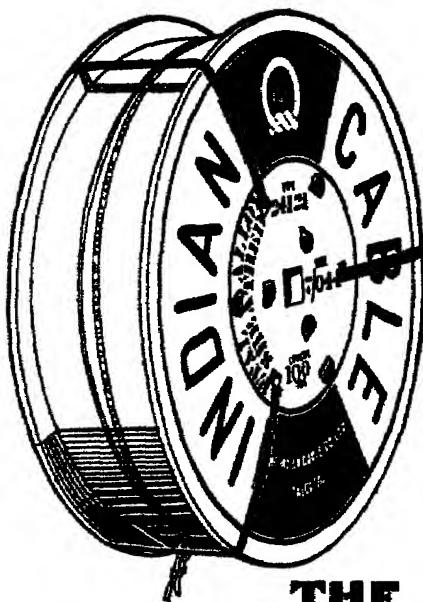
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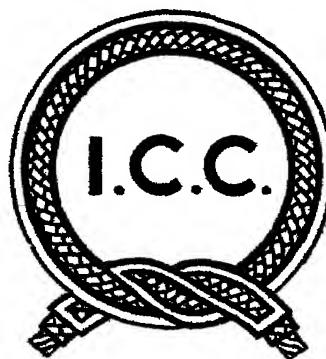
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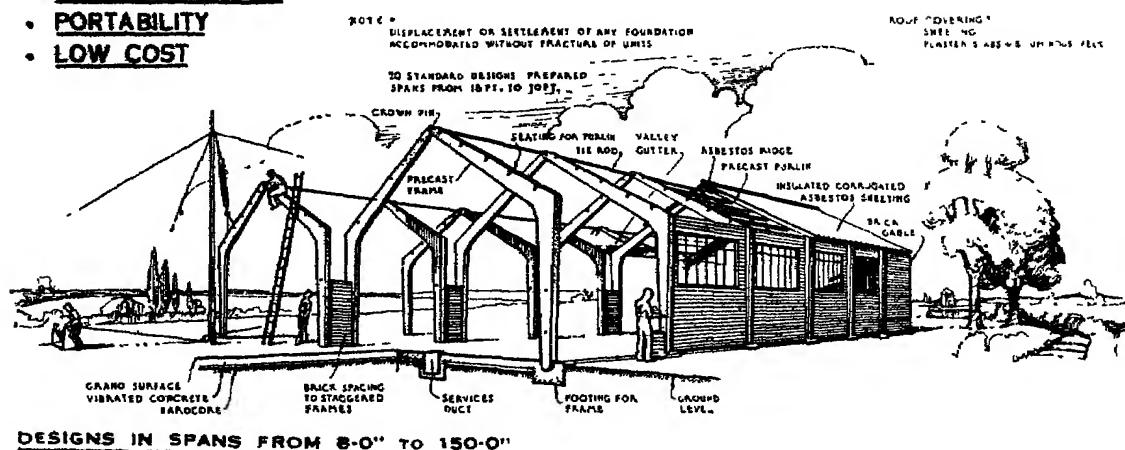
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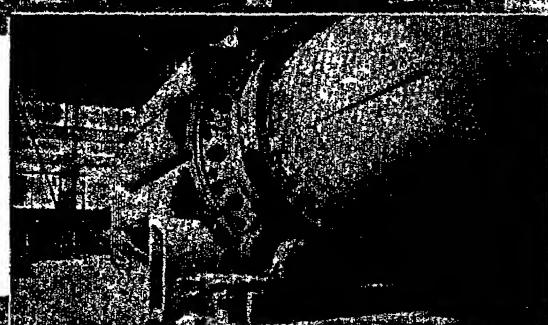


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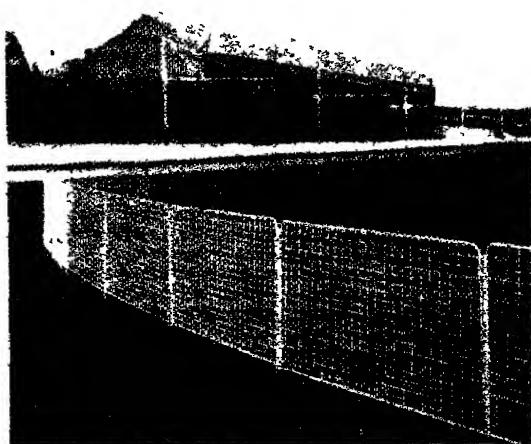
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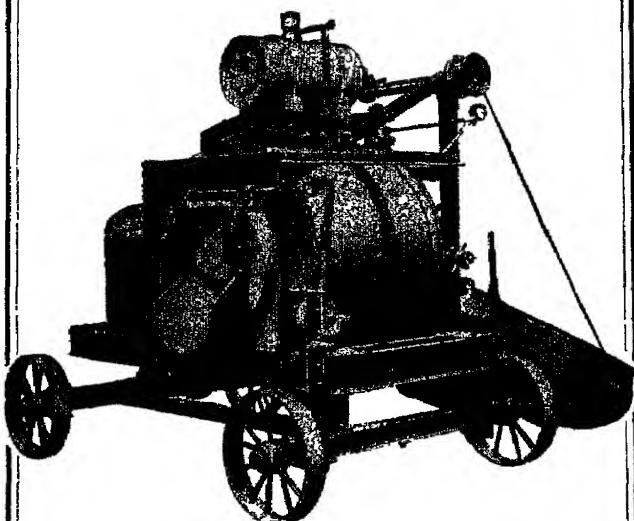
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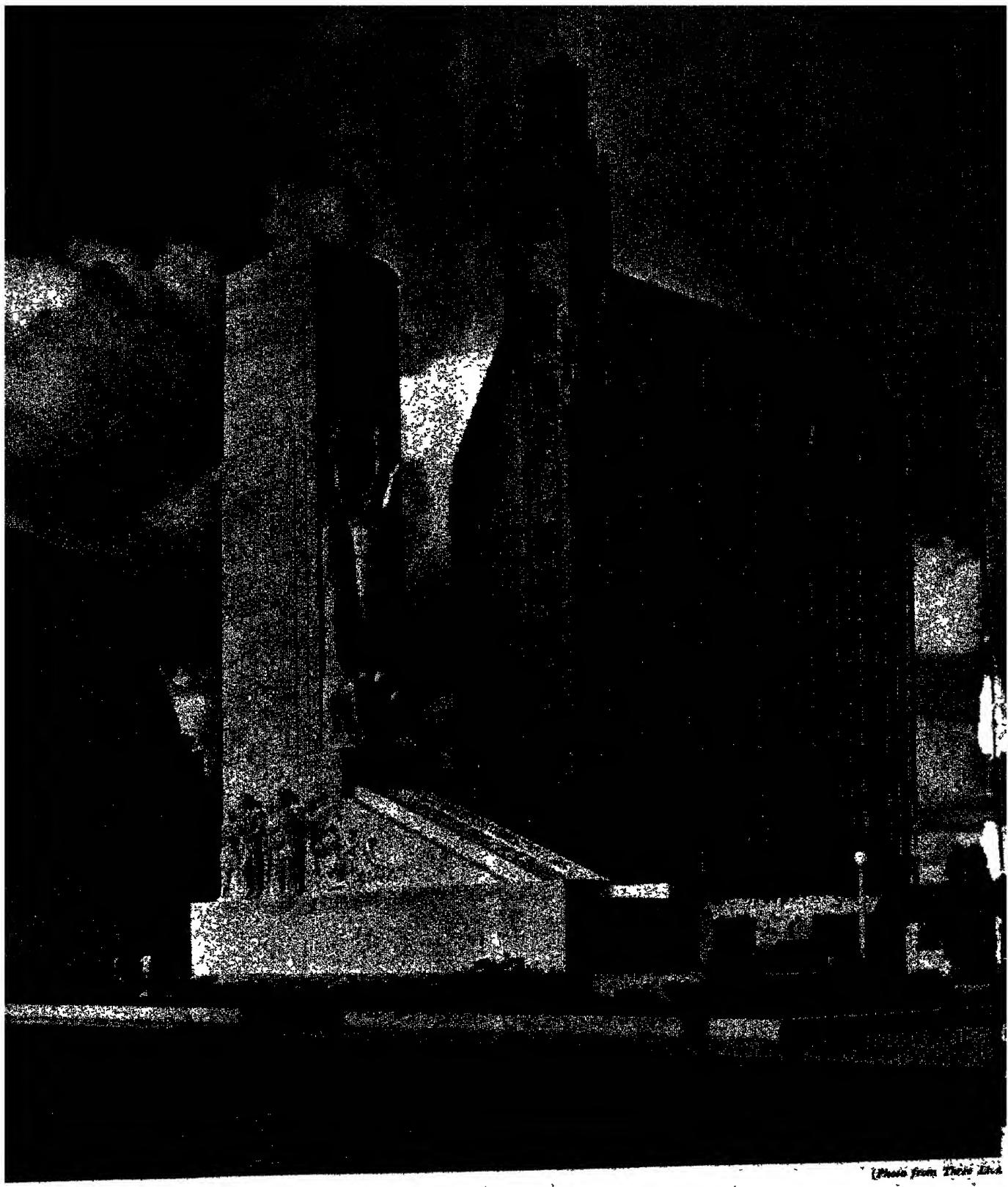
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